REPORT

TO

SANTA CLARA VALLEY

WATER CONSERVATION

COMMITTEE

ON

SANTA CLARA VALLEY WATER CONSERVATION PROJECT

MARCH, 1921

FRED H. TIBBETTS
CIVIL ENGINEER
SAN FRANCISCO, CAL.

STEPHEN E. KIEFFER
CIVIL ENGINEER
SAN FRANCISCO, CAL.

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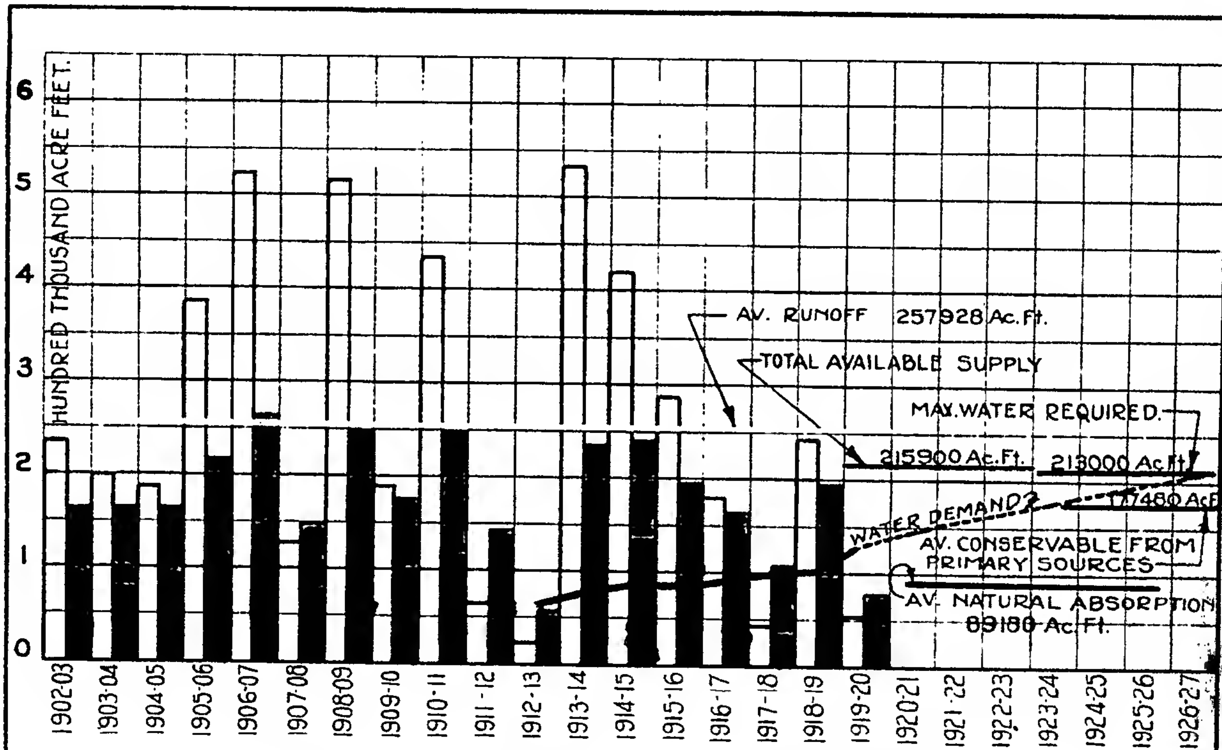
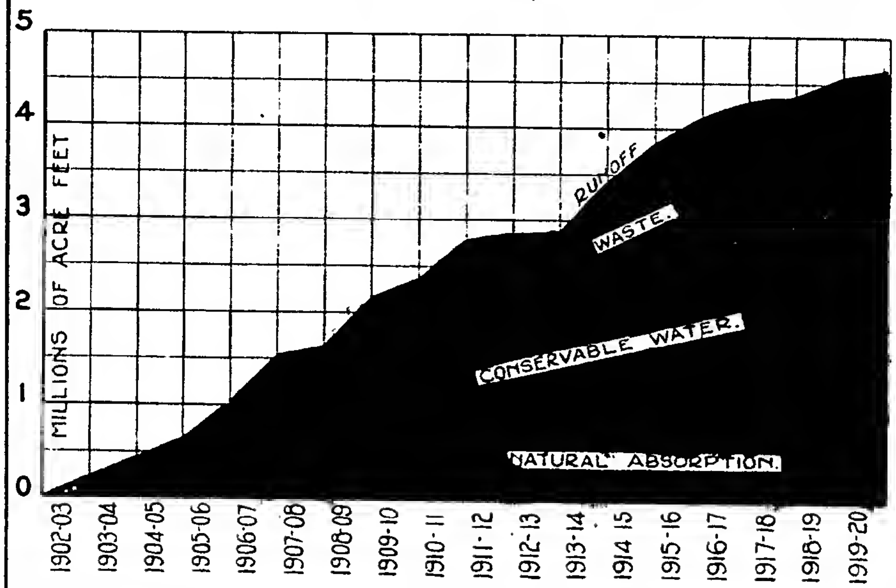


SEASONAL RUNOFF AND CONSERVATION



CUMULATIVE RUNOFF AND CONSERVATION

SAN JOSE CHAMBER OF COMMERCE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.

CONSERVABLE WATER

Fred H. Tibbetts, CONS. ENG'R.
Stephen E. Kieffer, CONS. ENG'R.

MARCH 1921.

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FRED. H. TIBBETTS
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ALASKA COMMERCIAL BUILDING
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March 23, 1921.

SANTA CLARA VALLEY WATER CONSERVATION PROJECT

LETTER OF TRANSMITTAL

Santa Clara Valley Water Conservation Committee,

San Jose, California.

Gentlemen:-

Acting under instructions of your Committee confirmed on July 31st, 1920, we have completed our investigations of the water resources of Santa Clara Valley, and submit herewith out report on the Santa Clara Valley Water Conservation Project. Preparation of this report has involved about eight months continuous work, and the expenditure of about $25,000. in field and office investigations. The report contains 163 typewritten pages, illustrated with 42 photographs, and 70 diagrams, charts and maps. During the course of the investigation, a new topographic map has been prepared of the Valley floor. About 600 wells have been located and measured, and the water levels determined. Selected wells have been periodically measured to determine their fluctuation, about 4000 measurements being recorded. The position, extent, origin, and movement of the underground water bodies has been determined. Economic studies have been made showing the present stage of development of the Valley, the growth of the demand for water, and the probable rate and

final extent of the Valley's development and water demand. The duty and cost of water under present conditions has been determined. A complete analytical study has been made of the runoff and rainfall of the surrounding watersheds, and the portions of this runoff which under natural conditions find their way from the stream beds to the underground water bodies, and the portions which are normally wasted into San Francisco Bay. Seventeen reservoir sites have been located and surveyed for the storage of surplus water in the mountains, and surveys have been made for construction works in certain creek beds designed to increase the natural percolation. Preliminary designs and cost estimates have been made for construction works designed to conserve all of the water which it is practical to save. A construction program has been outlined, and a scheme of organization and procedure has been suggested.

SUMMARY

Chapter I gives a general description of Santa Clara Valley showing its geographical position and commenting upon the unusually favorable conditions of topography, climate, transportation facilities, and residential and educational facilities, which has led to the unexcelled horticultural development of the Valley.

It is also shown that an impending water shortage led to the initiation of the present investigation, the results of which form this report.

Chapter II sketches the history and general development of the Valley, indicating its growth in population since its first settlement

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about 150 years ago, together with its growth in valuation. A crop survey is included showing the exact acreage in each of the six primary divisions in the Valley which is in various crops, and other non-agricultural or non-irrigated areas, including the areas in cities and towns. It is shown that the growth of the orchard industry is such that in 11 or 12 years all of the remaining available land will have been planted. It is concluded that the present development of the Valley is such that approximately 2/3 of the maximum demand for water has been reached, and that the rate of development is such that the maximum demand will probably be reached about the end of the next decade.

Chapter III gives the development in the Valley of irrigation, starting about 1900. The relatively small development of gravity irrigation ditches is indicated with brief descriptions of each surface system.

The volume of water utilized in gravity irrigation is given for the past 18 years.

The extent and distribution of irrigating pumping plants is given in some detail with the growth in number of plants for each division of the District since 1890. The capacity of the pumping plants is considered, and it is shown that under present conditions the cost of water supplied by the pumping plants is from $20.00 to $37.50 per acre per year.

About two-thirds of the irrigable agricultural lands were served with water in 1920, including 90½ percent of the orchard area.

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The duty of water for various crops is developed, and it is shown that in 1920 there should have been used 136,870 acre feet. The District contains a total net area of irrigable agricultural land of 127,212 acres, the total area in the District being 157,550 acres. Within the next decade the water demand will increase to a sustained maximum within the District of 203,000 acre feet per year, and within the Valley, South to Gilroy, including a 5% addition for high marginal areas, of 213,000 acre feet per year.

Chapter IV describes the water resources of the District. The tributary watersheds of the Valley are delineated and the total area is shown to be 576.7 square miles. This has been segregated into 28 different parts each having a separate drainage outlet into the District. An exhaustive analysis has been made of the rainfall of the entire watershed, using all available data extending back to 1849. The annual rainfall is tabulated for each of nine base stations from 1849 to date. The normal rainfall has been tabulated for each of the 28 watersheds as well as for different portions of the Valley floor. Normal rainfall has been deduced for 30 additional subsidiary stations. The runoff has been analysed for each of the various component watersheds based upon rainfall determinations and upon careful measurements of the actual runoff over portions of the watershed for considerable periods. The runoff has been computed for each year from 1902 to 1920, and it is finally shown that the average seasonal runoff is 267,905 acre feet, the maximum

being 542,405, and the minimum 24,425 ac. ft.

The natural underground water supply has been determined, based upon field measurements of seepage losses, in the various creek beds, and upon a study of the probable flow in each creek for the past 18 years. A study has been made from well logs of the available porosity of the underground material and its total available volume. It is concluded that in the West Side Division, for example, the average available porosity is 11.1%. The replenishment of the underground waters is computed for each stream, the portion of the total runoff absorbed in the creek beds, averaging 38%. The average total annual absorption is 89,180 ac. ft., varying from a maximum of 144,875 to a minimum of 19,965 ac. ft. Adding the average natural stream absorption to the average gravity irrigation, shows that the total thus obtained and theoretically usable averages but 102,230 ac. ft., or but 48% of the maximum requirement.

A study is made of the geological formation of the valley floor, especially of the location and extent of the water-bearing material. Underground water movements and well fluctuations are indicated, and the position of the low water plane is mapped, showing extensive areas where the depth to water exceeds 100 feet. It is especially noticable that the wells respond at once to stream-flow in the adjoining creeks, and it is concluded that could this stream-flow be artificially prolonged, then the spring rise of the water plane would be correspondingly increased. The position of the water plane in 1904 was determined, and the average fall in the water plane for the last four years is especially significant. This fall which

is shown to be permanent, averages 4 to 5 feet per year in the West Side Division, and corresponds very closely to the result of analytical studies of the deficiency in natural replenishment as compared with water used in the last four years, the drop in the water plane being equal to this average deficiency multiplied by the average available porosity of the water-bearing material. One of the most important conclusions of the report is that with average natural replenishment and the water demand which will be reached within ten years, the average annual permanent drop of the water plane will be 5-1/4 feet, and in the West Side Division alone, over 6 feet.

Chapter V on the conservation and use of water, describes the construction work proposed for the maximum practical amount of water conservation. 17 different reservoir sites are listed and mapped, together with the available runoff and storage capacity of each, with brief descriptions of construction work proposed for each, and general descriptions of each reservoir and dam site. A study is made of the probable silting of the reservoirs, and it is shown that this is unimportant. The proposed utilization of the storage reservoirs is described, the important feature being the shifting of water from the Coyote watershed which has a large surplus, diagonally across the District to the West Side Division, which has the greatest deficiency. It is shown that the Coyote Valley can be provided for, after which there will be left an average surplus from the Coyote reservoirs of 34,000 ac. ft., for other portions of the Valley. Various combinations are indicated for the use of the West Side reservoirs. Descriptions are given of low spreading dams proposed for creek beds to increase the rate of percolation, and thus

increase the amounts of water which can be ultimately conserved and which cannot be feasibly stored in the mountains. Such dams are particularly proposed upon the Los Gatos and Guadalupe Creeks. An analysis is made of the reused ground water in the lower ends of the District, and an estimate of the amounts of water for various divisions which may be re-used. A final tabulation summary for the entire District of the water demand and the supplies which may be available to satisfy this demand, shows that to meet the estimated demand of 213,000 acre feet, there may be available from primary sources of supply (mountain storage and spreading dams) 177,480 acre feet, and from secondary sources of supply (re-used water obtained by pumping in the low-lying areas) 38,425 ac.ft, or a total of 215,900 acre feet, or about 3% in excess of the maximum demand. It is possible to ultimately obtain about 25,000 more acre feet by additional and more expensive storage on the Coyote and Uvas.

Chapter VI describes the proposed plan of construction with preliminary cost estimates. Cement lined conduits are in the main provided to convey the stored water to the points where needed. Local distribution is not included. It may be effected by a continuation of the present system of allowing water to percolate from the stream beds to the underlying water bodies, and then recovering it by individual small pumping plants; or if desired, a surface distribution system may be installed in whole or in part. Spreading works on a number of stream channels are also proposed. In the two lower divisions (Palo Alto and Milpitas Divisions) supplementary supplies are provided through the use of two large central pumping plants which will pump water from a line of wells along the lower margin of the District intended to

intercept the final remnant of the underflow which may otherwise be permanently lost by passing outward under the Bay.

The estimated cost of the mountain reservoirs is $6,879,795; of the reservoir connecting conduits, $242,500; central pumping plants and conduits, $3,555,200; spreading dams, $270,000; total $10,947,495, or $69.50 per acre of the gross district acreage of 157,550 acres.

Chapter VII is furnished by the Committee's Attorney, Mr. L.D. Bohnett, and indicates the proposed organization of the District by legislative enactment. The District is to be divided into six divisions, the Morgan Hill-Gilroy, and the Palo Alto Divisions, with one elected trustee each, the Milpitas and Evergreen Divisions, with one trustee for the two, and the large West Side and Coyote Divisions with two trustees each. The proposed construction work for each division may be outlined by the Trustees of the District under the advice of their Engineer, and after detailed plans are prepared, assessments for the work may be spread upon the area benefitted according to the benefits derived by each portion of the area, after which the people in the District affected will vote upon the proposed project, by dollars of assessed valuation.

RECOMMENDATIONS

It is recommended that the District be organized as outlined, as rapidly as possible, and that the construction of the main reservoirs and conduit lines, especially to supply the West Side Division, be pushed as rapidly as possible, as it is demonstrated that unless this be done development of the Valley will be checked because of insufficient water; a permanent decline in the water plane having commenced about 1917, since the demand for water then began to exceed the natural supply.

If the complete conservation program be consummated, there is available, at the moderate cost of $69.50 per acre, interest on which at 6% would be but $4.17 per acre per year, sufficient water to enable the full development of the entire district, and to guarantee a certain and sufficient water supply.

Fred H. Tibbetts
Consulting Engineer.

Stephen E. Kieffer
Consulting Engineer.

CHAPTER I.

DESCRIPTION OF TERRITORY AND REASON FOR INVESTIGATION.

GENERAL

From the earliest days of California's development the Santa Clara Valley has always been held in the popular mind as one of the garden spots of the State. Its favorable geographical location, topography, climate and general productivity have combined to produce a community of the highest type with resulting high property values.

Probably no other small local community in the country has such a worldwide reputation, gained from a single fruit product, to the growth of which the soil and climate are particularly adapted. Famous as the home of the prune it is also a heavy producer of a great variety of deciduous fruits, nuts and vines, and special annual field crops.

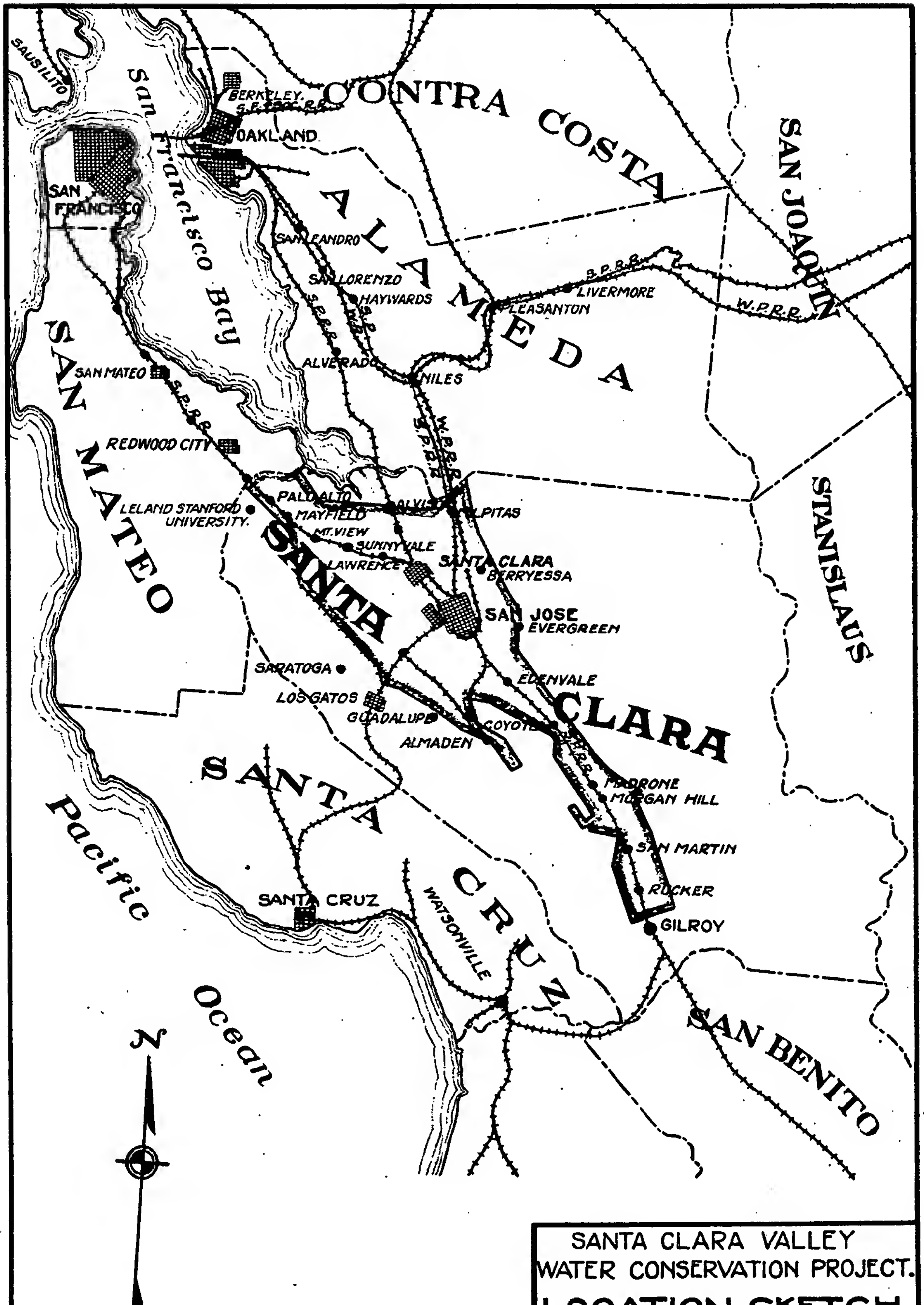
It is a valley of intensive planting and high cultivation; a veritable edition de luxe of horticultural and agricultural development. The fame of its beautifully kept orchards, attractive homes and wonderful roads is not greater than that of its scenic beauty, for which it is as much the Mecca of the tourist as any of the other show places of the State.

GEOGRAPHY (Plate 2)

The Santa Clara Valley is located Southerly from the Bay of San Francisco. The Coast Range mountains on the West and the Mt. Hamilton range on the East approach each other at a point about 20 miles South of the Southern end of San Francisco Bay and enclose the principal valley in a bowl shaped and nearly circular area with greatest general dimensions North and South 20 miles, and East and West 13 miles. At the South side the encircling mountains are broken by a pass known as the Lower Gorge of the Coyote, which opens into an extension of the main valley reaching as far South as Gilroy, with a length of 18 miles and greatest width of 4 miles. This extension is variously known locally as the Coyote or Gilroy valley. The total length of the combined valleys from the County line at Palo Alto to Gilroy is 46 miles. Within this area is included the major portion of the valley lands of Santa Clara County.

Many streams enter the valley from the surrounding mountains. Principal among these are the Coyote, Uvas, and Llagas creeks on the South and Alamitos, Guadalupe, Los Gatos, Campbell and Stevens creeks on the West.

Numerous towns and cities are scattered over the area. The principal city, situated in the geographical center of the main valley, is San Jose, with a population of about 40,000. Quite uniformly distributed from North to South are the smaller cities and towns of Palo Alto, Mayfield, Mountain View, Milpitas, Santa Clara, Los Gatos, Saratoga, Campbell, Morgan Hill and Gilroy.



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.

LOCATION SKETCH.

Fred H. Tibbetts
CONS. ENG'R.

Stephen E. Kieffer.
CONS. ENG'R.

March 1921

PLATE 2

TOPOGRAPHY AND CLIMATE

The topography of the Valley is that of a bowl shaped amphitheater, with an open side to the North facing San Francisco Bay. At one time the waters of the sea probably covered the entire valley, forming an enlarged Bay, with the outlet to the South through the Lower Gorge and Gilroy Valley.

With the subsidence of the sea, or elevation of the land, the gradual wearing from the surrounding mountains has filled the valley floor to great depths with the gravels, sands and clays of erosion. This process has resulted in sloping the plains from the West, South, and East toward the North center at present sea level. The slopes are quite steep next the hills, gradually flattening as sea level is approached, with broad flat ridges or "cones" of greater or less local prominence created by the various streams as they have swung back and forth over the valley floor during flood and deposition periods. This building up by deposition of water borne materials has resulted in a most irregular arrangement of the gravels, sands and clays comprising the valley floor, but in general the materials shade from coarse gravels at the foothill margins to the fine sands and clays of the sea level. The local topography of the valley floor is wholly influenced by this building effect of the local streams, this in turn affecting the soil types and the resulting crops.

Elevations for the valley floor range from sea level on the North to an average of about 200 feet above sea on the East

and South and 300 feet on the West at the general line of the toe of the foothill slopes. A few small areas that might be classified as a part of the valley floor proper reach an elevation of 400 feet. The surrounding mountains have a maximum height on the West of 3,800 feet with an average height along the crest line of 2,400 feet, while on the East a maximum elevation of 4,400 feet is reached at Mt. Hamilton.

The Coast Range (or Santa Cruz) mountains on the West are for the most part heavily timbered and brush covered, coniferous trees largely prevailing. In the Easterly (or Mt. Hamilton) range the mountains are more open, with grass and brush cover and some secondary timber, mostly oak.

Climatically the Valley is highly favored. The surrounding mountains protect it from the frequency and sweep of the Western winds which prevail farther North in their passage through the Golden Gate and across the Northern Bay and hills into the great interior Valleys. The Coast Range which acts as a barrier and deflector for these ocean winds also holds back the coast fogs. In the same manner that the Valley is protected on the West from the winds and fog of the ocean it is also protected on the East by the Mt. Hamilton range, which acts as a barrier to the excessive summer heat of the interior valleys. While guarded in its summer climate by the agencies cited from the extremes of either prolonged valley heat or coast rawness there is a moderate but not prolonged summer heat, tempered in the main Valley by proximity to the open Bay on the North.

Thus placed between the ocean and the great interior valley of the San Joaquin, but protected from the extremes of heat or cold of either, and with the tempering effect of proximity to salt water in the sheltered portion of San Francisco Bay, the climate is moderate in all its extremes, conducive to pleasant living and work, ideal for residence, and one particularly favorable to the deciduous crops produced.

TRANSPORTATION AND BUSINESS FACILITIES

A glance at the general map shows that the Valley has a veritable net work of steam and electric railways. The Southern Pacific main Coast Line traverses the entire length of the Valley, with brances on the East and West sides connecting with the East Bay Cities and transcontinental lines Eastward, and the Santa Cruz mountain and coast resorts Westward.

A branch extension of the Western Pacific is now building from Oakland to San Jose. Surburban electric lines of the Southern Pacific connect San Jose with the cities of Los Gatos, Saratoga, Los Altos and Palo Alto on the West and North and Alum Rock Park on the East. San Jose has an extensive system of surface street electric railways.

The great volume of business created by the crops produced in the valley guarantees ample rail transportation, and this in turn stimulates manufacturing and general business. Numerous manufacturing plants are located in the Valley, this phase of its development having assumed large proportions.

RESIDENTIAL AND EDUCATIONAL FACILITIES

Proximity to the large centers of population in San Francisco and the combined East Bay Cities, with the facilities of connecting steam and electric railways, and automobile highways of the best type, give a suburban character to the region and add to its desirability as a place of residence quite apart from its local business aspect. Daily commuting from San Jose to San Francisco, with a two hour train schedule, is quite possible and is common from Los Altos and Palo Alto. The urban population of the Valley, distributed among numerous cities and towns, is large, but because of the delightful climate, beautiful location and unusual local facilities for home comforts created by good roads, telephones and electric light and power, the distribution of country population is general and intensive, the acreage property subdivisions being small. Following the general development the residential development has in large part partaken of the character of a large unit suburban community, of which San Jose is a center.

Naturally in such a community the highest type of educational facilities may be looked for, and found. The public school system is in keeping with the density and high type of population, and is crowned with unusually favorable and accessible University privileges. Within the Valley itself, at Palo Alto, is Stanford University and only fifty miles away at Berkeley is the University of California, - two of the largest and most noted Universities of the land. At Santa Clara are located the well known Santa Clara College and University of the Pacific.

GENERAL DEVELOPMENT

The general development of the Valley, from which it has gained its principal fame and wealth, has been along horticultural lines. Primarily noted for its orchards, largely of prunes, the future development may be expected to be along the same proportionate lines of distribution. This will imply a constant increase in the orchard area. Agricultural and special annual crops will also keep pace proportionately. The advantages of irrigation for all crops has been increasingly realized of recent years, with the result that demand for irrigation water has increased in even greater ratio than the planting.

At some point, which apparently has been reached or passed, the natural replenishment of the ground waters, from which the present irrigation supply is principally drawn, will fail to adequately meet demands upon it. Such a failure will mean arrested new development, and reduced returns from existing development.

Toward the solution of this problem of an adequate irrigation water supply the present investigation has been directed.

NATURE OF INVESTIGATION

Realizing the necessity of making provision for the future of the valley by the conservation of its water supply active steps were taken early in 1920, by various organizations in the Valley, to create a representative body for the purpose of studying the situation. Resulting from this movement the Santa Clara Valley Water Conservation Committee was formed, with the following personnel:

Chas. E. Warren, Pres.,Cupertino,
E. K. Clendenning, Sec., Campbell,
J. W. Breton, Morgan Hill,
E. O. Billwiller, San Jose,
Robert Britton, Morgan Hill,
W. H. Crothers, Campbell,
J. K. Durst, Sunnyvale,
E. A. Hayes, San Jose,
T. J. Henderson, Campbell,
A. R. McClay, Evergreen,
Irwin E. Pomeroy, Santa Clara,
F. M. Righter, Campbell,
F. C. Wilson, Sunnyvale,
A. P. Marston, Campbell,
H. C. Hagan, Gilroy,
Norwood D. Smith, Palo Alto,
L. Woodard, Campbell,
J. F. Byxbee, Palo Alto,
W. D. Wasson, Palo Alto,
A. W. Greathead, San Jose,

Executive Committee

L. Woodard,
Chas. E. Warren,
E. K. Clendenning,
F. C. Wilson,
Irwin E. Pomeroy,
W. H. Crothers,
Geo. Bray.

Finance Committee

E. A. Hayes,
L. Woodard,
Geo. Bray.

Funds were raised by contributions from the Board of Supervisors of Santa Clara County, Chamber of Commerce, and private subscriptions.

Consulting engineers were retained by the Committee to make a detailed engineering investigation and report upon the entire irrigation water supply problem of the Valley. This investigation was started in August,1920, and has been carried on continuously since that time. The present report is intended to set forth the results and conclusions of that investigation.

The engineers were instructed by the Committee to study all phases of the subject, with particular reference to methods of conservation of waste flood waters. The territory to be covered was all that portion within the principal valleys of Santa Clara County from the County line on the North to Gilroy on the South.

The scope of the investigation has included among its principal features a detailed analysis of the rainfall and runoff of the tributary watersheds, storage reservoir surveys and studies, a complete crop survey, a well survey, including delineation of the underground water table, a topographical survey of the valley floor, stream measurements to determine rates of gravel absorption, and a survey of the principal stream beds to determine their absorptive capacity.

CHAPTER II.

HISTORY AND GENERAL DEVELOPMENT OF THE VALLEY

SETTLEMENT OF VALLEY

The settlement about 150 years ago of Santa Clara Valley and its important cities of San Jose, Santa Clara, and Gilroy, forms one of the most interesting and romantic chapters of the early history of California.

The Valley was discovered on November 2, 1769, by Spaniards, under the command of Captain Gaspar de Portola. The Mission of Santa Clara was founded January 12, 1777, under instructions from Father Junipero Serra. The civil settlement of the Pueblo de San Jose was founded on the 29th of November, 1777, being the first pueblo or town in California. In these early days the Valley was a beautiful park, dotted with magnificent oaks and abounding in wild game. Foreigners began to penetrate into the Valley in 1814, one of the earliest being John Gilroy, who founded the town bearing his name, and who is claimed to have been the first permanent foreign settler in the State of California.

From the view point of the present report, it is interesting to note that the site of the Santa Clara Mission, as well as the pueblo de San Jose was repeatedly changed because of destructive floods from the Guadalupe River. The growth in population of San Jose and of the Valley was for a time exceedingly slow until in 1846 control passed into the hands of the Americans under Colonel Fremont. The first legislature of the

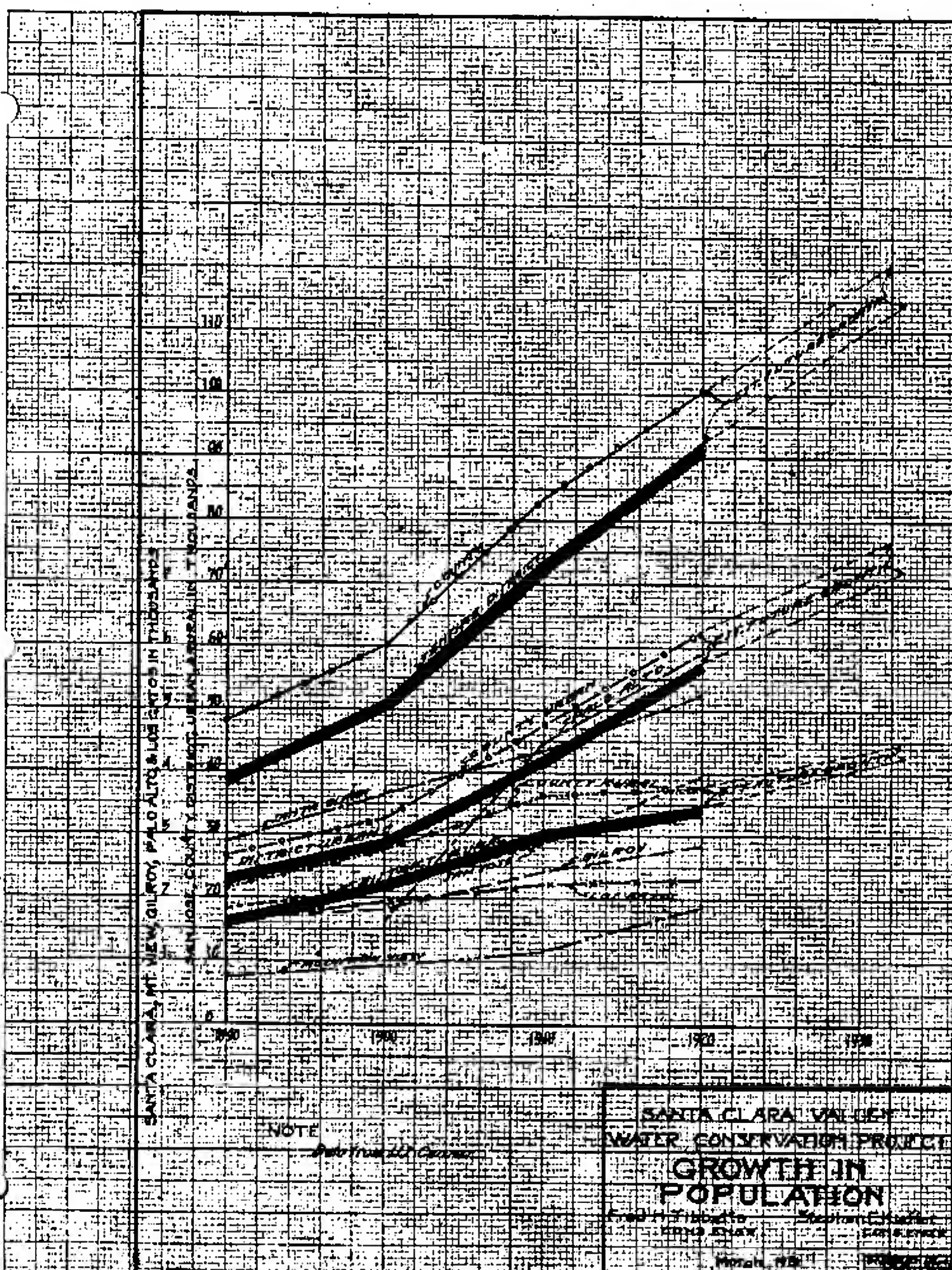
new State of California convened in San Jose, December 15, 1849, and during the latter half of the last century the growth of San Jose and the surrounding Santa Clara Valley has been rapid and continuous.

GROWTH IN POPULATION

At the beginning of the 19th Century the population of San Jose was given as 170. In 1831 it was 524. The real substantial growth of the City and Valley began about 1850.

During the last 50 years from 1870 to 1920, the population of the county has increased from about 26,000 to about 101,000, or about 290 percent. The City of San Jose increased from about 9000 to nearly 40,000, or about 345 percent.

On Plate 3 is shown the growth in population as taken from the U.S. Census Records for the 30 year period from 1890 to 1920 for the county, and for the cities of San Jose, Santa Clara, Palo Alto, Los Gatos, Gilroy and Mountain View. It will be seen that during this 30-year period the increase in the county has been from about 48,000 to about 101,000, or about 110 percent. It is interesting to note that during this period of great orchard development, the increase in the urban population of the incorporated towns in the Valley, including San Jose, Santa Clara, Palo Alto, Los Gatos, Mountain View, Gilroy, Alviso, Morgan Hill, Sunnyvale, and Mayfield, was from about 27,000 to about 62,000, or about 130 percent, and the increase in the remainder or rural portion of the county was from 21,000 to 38,000, or about 81 percent.



NOTE
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
GROWTH IN
POPULATION

PLATE 3

DISTRICT POPULATION

Approximate estimates have been made of population and valuation within the portion of the county included in the boundaries of the proposed irrigation district of about 157,550 acres. These estimates indicate roughly that about 80% of the population, and 90% of the valuation of the entire county is in the proposed district. In the past 30 years the urban population of the proposed District has increased from about 23,000 to about 57,000, or about 148% and the rural population from about 16,000 to about 35,000, or about 119%. In 1890, 41% of the District's population was classified as rural, this proportion having decreased to 38% in 1920, largely due to the rapid growth of the town of Palo Alto. Estimating on the basis of a total agricultural area in the District of 141,419 acres, and average size of family per holding of agricultural land or per "ranch" of four, then in 1890 the average holding would have been about 35 acres, and in 1920, about 16 acres.

In the orchard section to be included in the development work proposed in this report, the rural population quite generally enjoys most of the advantages of urban residence, including excellent roads throughout all seasons of the year, together with interurban and electric railroads, interurban telephone service, and free delivery of mail and of retail goods.

These unusual refinements and comforts of rural life have quite likely been the determining factor in successfully conteracting the country-wide tendency toward rapid increase of urban population. Were

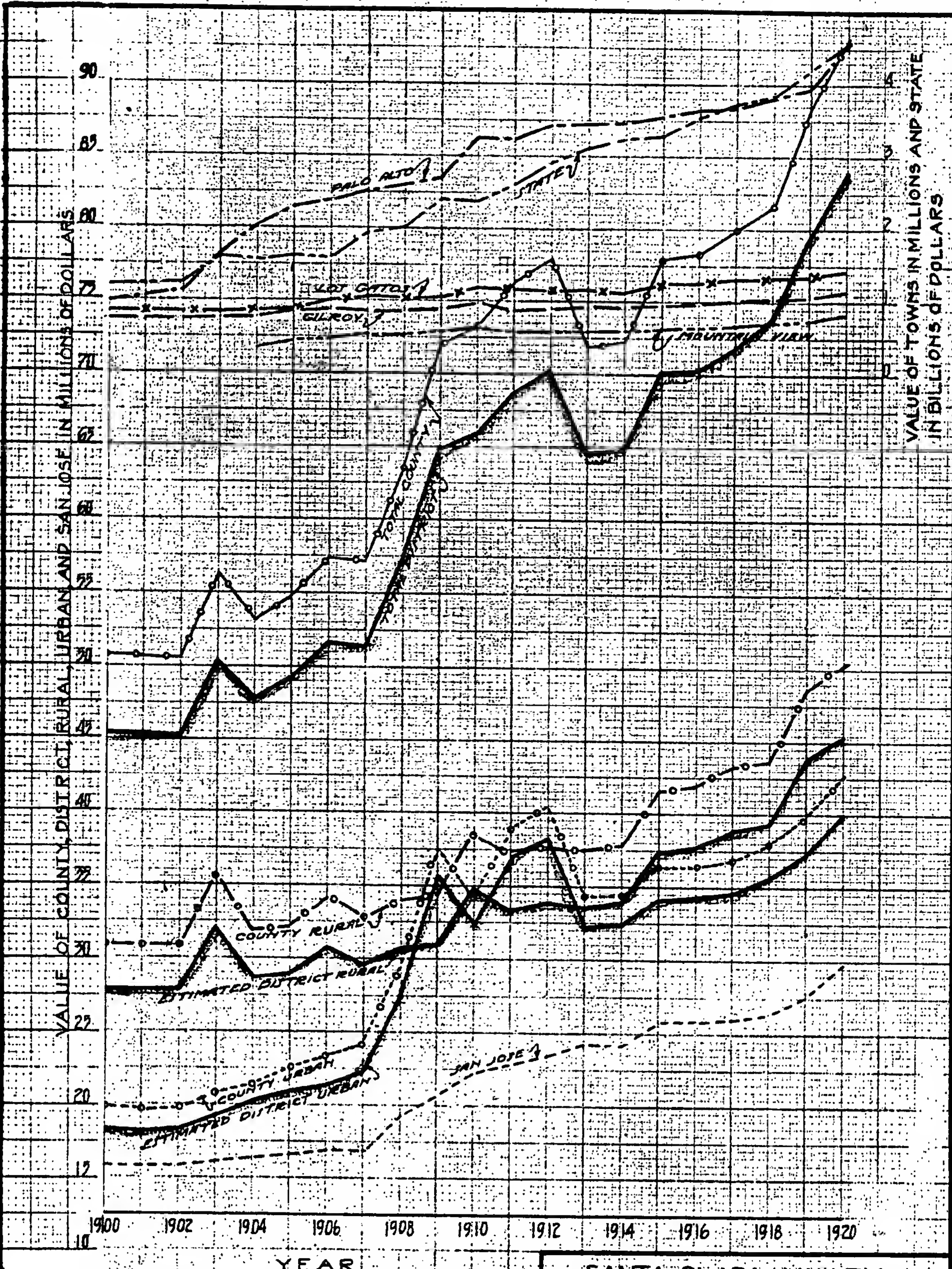
it not for the inclusion of Palo Alto, which has shown abnormal growth during the last 20 years because of its educational advantages, and its use as a San Francisco residence suburb, the relative proportions of rural and urban population in the District would have been almost exactly stationary for the last 30 years.

The statistics given indicate a very normal and healthy growth sure to continue steadily for many years, and also indicate that the bulk of the future development in the population of the county, especially its rural population, will be within the boundaries of the proposed District.

GROWTH IN VALUATION

ASSESSED VALUATIONS

Land values are subject to wide variation, and in general can be studied best by compilations of the county assessments. Such assessments are shown on Plate 4 for the last 20-year period from 1900 to 1920. During that period the total assessed valuation in the county has increased from about $51,000,000 to about $93,000,000, or about 84%. During the same period the total assessed valuation of the state has increased from $1,200,000,000 to about $4,600,000,000, or about 285%. The urban portion of the county included in the incorporated towns has increased from $19,842,000 to $42,664,000, or about 115%, and the remainder or rural portion from $30,889,000 to $50,476,000, or about 63%. Corresponding figures for property within the proposed District show an increase in valuation in the last 20 years from about $46,000,000 to about $85,000,000, or about 85%. The urban portion of the District has increased from about $18,000,000 to about



NOTE
Data from Records of Santa Clara County Recorder's Office

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

GROWTH IN VALUATION

Fred H Tibbetts, CONS. ENG'R
Stephen F. Kieffer, CONS. ENG'R.

March 1921

PLATE 4

$40,000,000, or about 122%, and the rural portion from about $28,000,000 to about $45,000,000, or about 61%. In 1900 the rural portion of the District composed about 61% of its total valuation, in 1910, 53%, and in 1920, 53%.

Prevailing high prices during the war and the continued productiveness of the soil, has caused land valuations probably as high as anywhere in the country, and it is not now uncommon for bearing orchards of prunes and apricots to sell as high as $2000 per acre, and bare land suitable for orchards, from $400 to $600 per acre. There seems no probability of these values being appreciably reduced providing productiveness of the orchards does not decline because of the depletion of the water supply.

MARKET VALUATION

The proposed District includes approximately 90% of the total county valuation. If assessed valuations be assumed to represent 60% of true market values, then by comparison with the preceding population studies, and the following land classifications, it can be shown that the market values of assessed property in the District averaged $1500 per capita, in 1900, and $1530 in 1920, or about $6000 per family of four; also that the average value of rural property in 1900 was $542 per acre, and in 1920, $1000 per acre. It is doubtful if anywhere else in the country can be found so extensive an agricultural area with such high average valuations and large per capita holdings.

CROP SURVEY

During the course of the present investigation, a careful detailed field survey has been made of the entire area included within the boundary lines of the proposed Irrigation and Water Conservation District of 157,550 acres. No attempt will be made to reproduce the detailed map compiled from this survey, but the original of the map is on file with the records of the Water Conservation Committee. The agricultural areas with a gross acreage of 141,419 acres were classified according to the general crops raised, and the non-agricultural areas were farther classified as shown. In order to obtain accurate data for the areas now using water, the agricultural areas were farther classified into irrigated land, and into non-irrigated but irrigable land, and into an area arbitrarily segregated out of the irrigable and irrigated lands and assumed to average 10% thereof, such area being set aside for roads, buildings, rights of way, drying grounds, etc., but not including the areas in cities and towns which were separately segregated.

The detailed summaries of the crop census by divisions, and the total for the proposed district is shown below, the divisions corresponding to those recommended for organization purposes.

TABLE 1.

CROP AND LAND CLASSIFICATION

CLASSIFICATION	IRRIGATED NET AREA (ACRES)	NON-IRRIGATED IRRIGABLE NET AREA (ACRES)	NON-IRRIGATED ROADS, BLDG. ETC. (ACRES)	GROSS AREA (ACRES)
PALO ALTO DIVISION				
Orchards	643	204	94	941
Truck and Berries	1221		136	1357
Alfalfa, Sugar Beets, etc.	396		44	440
Grain and Hay		2034	236	2270
Total Agricultural Area	2260	2238	510	5008
Hills				87
Cities and Towns				1409
Total Non-Agricultural Area				1496
Total Area	2260	2238	510	6504
WEST SIDE DIVISION				
Orchards	38623	3243	4651	46517
Vineyards		1261	140	1401
Truck and Berries	3961		440	4401
Alfalfa, Sugar Beets, etc.	3609		401	4010
Grain and Hay		12223	1404	13627
Total Agricultural Area	46193	16727	7036	69956
Hills				1008
Creeks				450
Cities and Towns				5461
Total Non-Agricultural Area				6919
Total Area	46193	16727	7036	76875
COYOTE DIVISION				
Orchards	12095	900	1444	14439
Vineyards		357	40	397
Truck and Berries	2840		315	3155
Alfalfa, Sugar Beets, etc.	5539		616	6155
Grain and Hay		8026	891	8917
Total Agricultural Area	20474	9283	3306	33063
Hills				2668
Creeks				922
Cities and Towns				3275
Total Non-Agricultural Area				6865
Total Area	20474	9283	3306	39928

TABLE 1. - Con.

CROP AND LAND CLASSIFICATION

CLASSIFICATION	IRRIGATED NET AREA (ACRES)	NON-IRRIGATED IRRIGABLE NET AREA (ACRES)	NON-IRRIGATED ROADS, BLDG. ETC. (ACRES)	GROSS AREA (ACRES)
MILPITAS DIVISION				
Orchards	350		39	389
Truck and Berries	1692		188	1880
Alfalfa, Sugar Beets, Etc.	171		19	190
Grain and Hay		1723	191	1914
Total Agricultural Area	2213	1723	437	4373
Creeks				43
Cities and Towns				9
Total Non-Agricultural Area				52
Total Area	2213	1723	437	4425
EVERGREEN DIVISION				
Orchards	4209	1503	635	6347
Vineyards		23	2	25
Truck and Berries	343		38	381
Alfalfa, Sugar Beets, Etc.	390		43	433
Grain and Hay		2854	325	3179
Total Agricultural Area	4942	4380	1043	10365
Hills				77
Creeks				15
Swamps				250
Total Non-Agricultural Area				342
Total Area	4942	4380	1043	10707
MORGAN HILL - GILROY DIVISION				
Orchards	9022	733	1083	10838
Vineyards		1269	141	1410
Truck and Berries	526		58	584
Alfalfa, Sugar Beets, Etc.	412		46	458
Grain and Hay		4817	547	5364
Total Agricultural Area	9960	6819	1875	18654
Hills				202
Creeks				128
Cities and Towns				127
Total Non-Agricultural Area				457
Total Area	9960	6819	1875	19101

TABLE 1. - Con.

CROP AND LAND CLASSIFICATION

ENTIRE DISTRICT

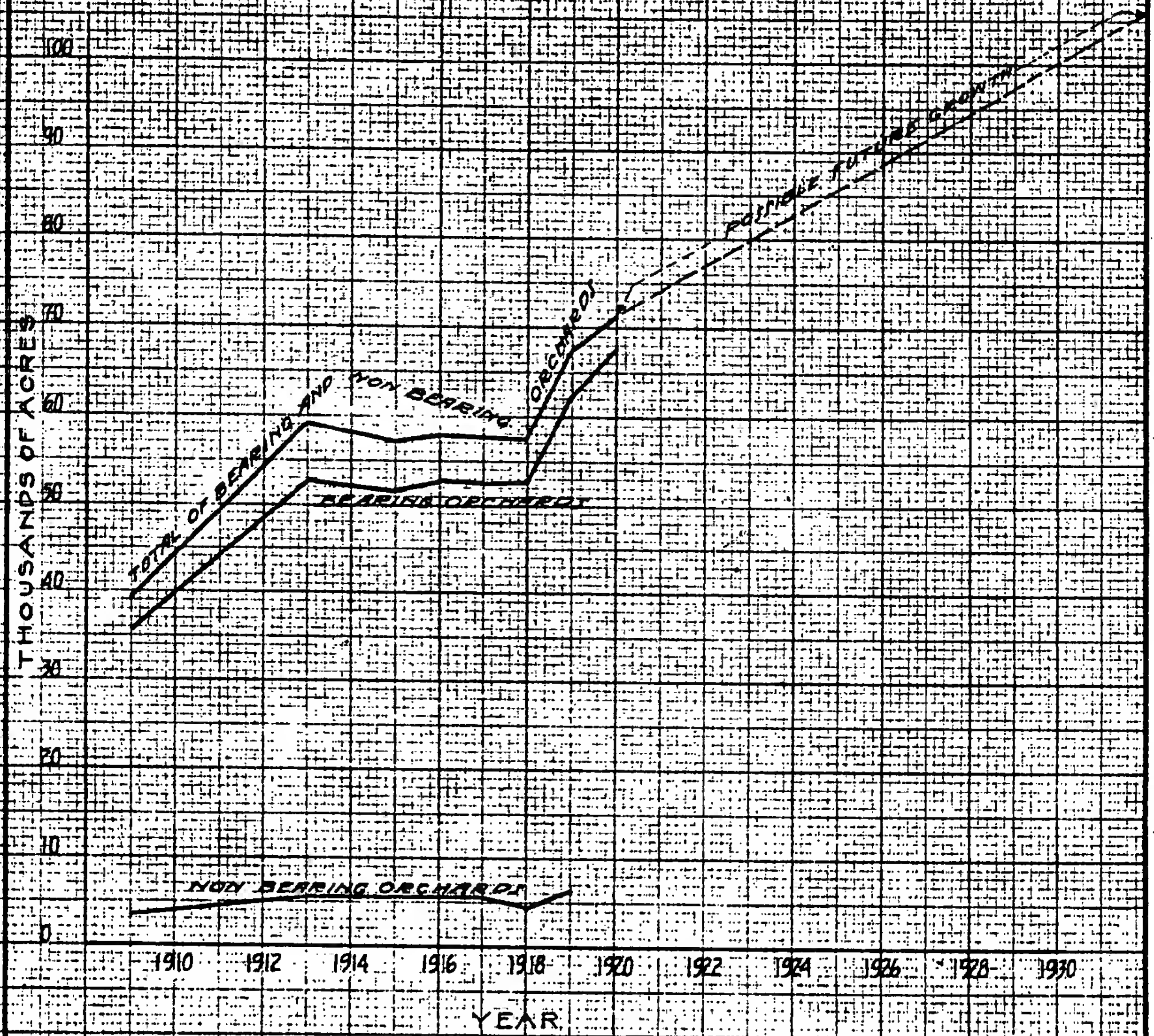
CLASSIFICATION	IRRIGATED NET AREA (ACRES)	NON-IRRIGATED IRRIGABLE NET AREA (ACRES)	NON-IRRIGATED ROADS, BLDGS. ETC. (ACRES)	GROSS AREA (ACRES)
Orchards	64942	6583	7946	79471
Vineyards		2910	323	3233
Truck and Berries	10583		1175	11758
Alfalfa, Sugar Beets, Etc.	10517		1169	11686
Grain and Hay		31677	3594	35271
Total Agricultural Area	86042	41170	14207	141419
Hills				4042
Creeks				1558
Swamps				250
Cities and Towns				10281
Total Non-Agricultural Area				16131
Total Area	86042	41170	14207	157550

GROWTH OF ORCHARD INDUSTRY

PRESENT DEVELOPMENT

Santa Clara Valley is pre-eminently an orchard section easily leading all other sections in the country in the growth of deciduous fruits, especially of prunes. The county produces one-half or more of the total prunes grown in the United States. The average yield for the last several years is given as about 85 million pounds of dried prunes, varying from 45 to 130 million pounds, with 120 million suggested as the normal yield.

Plate 5 shows the growth in orchard acreage for the last 12 years, 1909 to 1920, inclusive, from data of the United States Census Bureau, and of the County Assessor. It indicates that the total acreage of bearing trees has very nearly doubled within the last 12 years, increasing from about 36,000 acres to about 66,000 acres, and the total acreage of bearing and non-bearing trees from about 39,000 to 71,000; an increase of about 3000 acres per year. The increase during the last two years has been about 14,000 acres. The acreage classified as non-bearing appears to have remained nearly constant at about 5000 acres, apparently indicating that there is a considerable acreage taken out or replaced each year. A crop census taken in 1913 of the total number of fruit trees in the county showed that prunes composed 69.6% of the total; peaches 8%; apricots 7.2%; cherries 4.8%; plums 3.6%; pears 1.8%; miscellaneous 5%.



NOTES

Data from County Assessor and U.S. Census.
Diagrams show net acreage which is assumed as 90% of gross acreage.
Diagram is for area in proposed district

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

GROWTH OF ORCHARDS

Fred H Tibbetts, CONS. ENGR.
Stephen E Kieffer, CONS. ENGR.

March 1921

PLATE 5

FUTURE DEVELOPMENT

The extent to which farther orchard development is possible can be approximately deduced from the preceding crop summaries. Of the total gross area of agricultural land of 141,419 acres, 79,471 acres, or about 56% is already in orchard. Of the balance, 35,271 acres or 25% is in grain and hay, and presumably could practically all be set out to orchard. The orchard area is then apparently capable of about a 45% increase over the present area. If the orchard area increases at the same average rate as shown on Plate 5; then during the next period of about the same length as shown on this Plate, or say 11 to 12 years, all of the remaining available land will have been planted to orchard. All of the remaining bare land of course will not be planted to orchard, but it is probable that essentially all of it will soon be in either orchard or in other irrigated crops.

It may be roughly concluded from the above and from the deductions of Chapter III, that the present development of the valley is such that approximately two-thirds of the maximum demand for water has been reached, and that if development is continued in the future at the average rate of the past decade, then the maximum demand will be reached shortly after the end of the next decade.

CHAPTER III.

DEVELOPMENT OF IRRIGATION

BEGINNINGS OF IRRIGATION

The general use of water for irrigating fruit orchards in Santa Clara Valley appears to have started just prior to the beginning of the present century. Prior to this time the prevailing opinion had been that irrigation in this locality was an unnecessary expense. The year 1898, however, was a particularly dry one, with about 1/2 of the normal rainfall, and was preceded and followed by other subnormal rainfall years. Wherever practicable, there was a general resort to irrigation, and a steady, though not rapid development for the next ten years both of surface stream and of well irrigation. Another very dry year in 1908 again greatly accelerated the extension of irrigation, especially from wells. In 1912 it was estimated that about 29% of the agricultural land in the valley was irrigated. In 1920 this had increased to 67½% with 90½% of all orchards watered, and it is estimated that within 10 years all the balance of the agricultural lands will be irrigated.

Of the benefits of orchard irrigation, Dr. Fortier says in the 1904 Dept. of Agr. Report on Irrigation in Santa Clara Valley, Pg.80:

> "Previous to the dry period beginning in 1898 a limited area was winter-irrigated with water obtained from the creeks, but the prevailing sentiment was opposed to irrigation. ······· The benefits resulting from a wise use of water in this valley have now, however, been clearly demonstrated. Some of the most apparent of these to the fruit grower have been the superior quality of the fruit produced, a greater regularity in bearing, and, more particularly, a large increase in yield."

SOURCES OF SUPPLY

Two entirely distinct sources of supply have been used for irrigation in the Santa Clara Valley, namely the surface streams and wells drawing on the underground water reservoir. The former has been much more important in the past than at present, while the latter is increasing at an accelerated rate. The underground reservoir formed by the porous spaces in the water-bearing gravel or sands underlying the orchards is annually replenished in the main by the surface streams. The wells through which water is drawn upward from the gravel reservoir to the orchard trees should be considered as an alternate portion of the distributing system connecting the streams with orchards; these wells being substituted for the surface ditch systems of distribution. The surface ditch distribution can be used only when the streams are flowing, ordinarily in January, February and March, and in dry seasons perhaps but a very small portion even of these months. The well system of distribution on the other hand, while not as cheap or as efficient, has the great advantage of drawing directly from the enormous equalizing reservoir formed by the underlying gravel beds, water being obtainable with almost uniform facility at any season of the year.

GRAVITY IRRIGATION DITCHES

MAXIMUM DEVELOPMENT

The extent of irrigation from gravity ditches diverting water from surface streams in the Santa Clara Valley has been relatively small. At the present time the area irrigated in this manner probably amounts to less than 3000 acres. Inasmuch as most of the runoff from the

streams occurs during a relatively short period during the winter, it is necessary for the water to be applied, during the winter and early spring. This practice of winter irrigation reached its largest development about 1904 to 1906, when from 12,000 to 14,000 acres were irrigated in this manner.

DUTY AND COST OF WATER

The depth of water applied, as shown by numerous measurements, varies from about 1.5 to 4 or 5 acre feet per acre gross during the period of irrigation. Measurements made by the Department of Agr. in 1904 on ditch systems diverting water from the Almaden, Los Gatos and Campbell Creeks, showed an average depth of 2.22 feet and an average cost per acre foot of $2.10, or about one-fourth to one-sixth the cost of pumped water.

Inasmuch as the amount of water diverted depends upon the natural stream flow which varies widely, the amount of water capable of diversion and hence the area irrigated also varies widely in different years, being quite small in dry years. In very wet years, with continuous and heavy winter precipitation, there is also a tendency to use less water for irrigation under these surface systems.

DECLINE OF GRAVITY IRRIGATION

The year 1907 was a year of heavy winter and spring rainfall, with a much reduced demand for gravity irrigation. The following year, 1908, however, was a very dry year, with small and intermittent stream flow making it impossible for the gravity diversions to furnish water for much more than one-half of the area previously irrigated, and hence many valuable orchards suffered for the want of water. This gave rise to the rapid development of wells, which quickly took the

place of winter irrigation. Following this dry period there was therefore a gradual decrease in the area irrigated under the gravity ditch systems, and since that time there has never been the demand that formerly existed, for water from the surface ditches. Many of the ditches have deteriorated greatly, and the rights of way on large portions of them have lapsed. Another contributing cause to the decrease in the practice of winter irrigation, is said to be the placing of a minimum charge on electric plants, thus inducing the farmers to use their pumps to as great an extent as possible, and thus satisfy all their needs for water. The orchardists also have found that they could secure more beneficial results from irrigation by pumping in the summer months. There is also the additional factor of uncertainty in the occurrence and amount of water available from the surface ditch systems, and the frequent necessity of having to take water at inconvenient or inopportune times. These causes have all tended to decrease the development of irrigation by surface ditches and increase the development of irrigation by wells. It will be elsewhere pointed out how this combined effect of the decrease in winter irrigation, and the increase in pumping, together with the effect of a series of dry years, has resulted in the rapid lowering of the ground water level in districts formerly largely supplied by winter irrigation.

PRINCIPAL SURFACE SYSTEMS

The largest development of irrigation ditches has occurred on Los Gatos Creek in the vicinity of Campbell, where two ditch companies, and one private ditch have constructed ditches whose aggregate length was at one time about 25 miles, capable of serving a maximum area of about 10,000 acres. There are also irrigation ditches diverting water

from Almaden Creek, Guadalupe Creek, Campbell Creek, Stevens Creek, Permanente Creek, and Penetencia Creek. See Plate 6 for the approximate maximum development of the different distribution systems and the points of diversion of each.

The following description of the various irrigation ditches, together with the areas irrigated and the amount of water used, has been gathered from all the available published data, including O. E. S. Bull. #254, and O. E. S. Bull. #158, U. S. Dept. of Agr., and from information furnished by those best informed concerning the various ditch systems.

KIRK DITCH (Fig. 1)

The oldest ditch diverting water from the Los Gatos Creek is the Kirk Ditch, owned and operated by an association of about twenty-five farmers under the name of Kirk Ditch Company. This ditch was built in about 1857 with its point of diversion on the right or easterly bank of Los Gatos Creek, about one and one-half miles above the Town of Campbell. It has a maximum capacity of about 40 second feet and serves about 1000 acres of land. It has the first right to water during dry years. However, the actual number of acres irrigated varies from year to year, depending upon the stream flow and has been as small as about 400 acres in such years as 1912.

The Ditch Company sells no water to any lands outside those owned by the members of the association.

SANTA CLARA VALLEY WATER COMPANY (Figs. 2 and 3)

The irrigation system of the Santa Clara Valley Water Company consists of about ten miles of ditches diverting water from Los Gatos Creek about one mile above the Town of Campbell, and about one-half

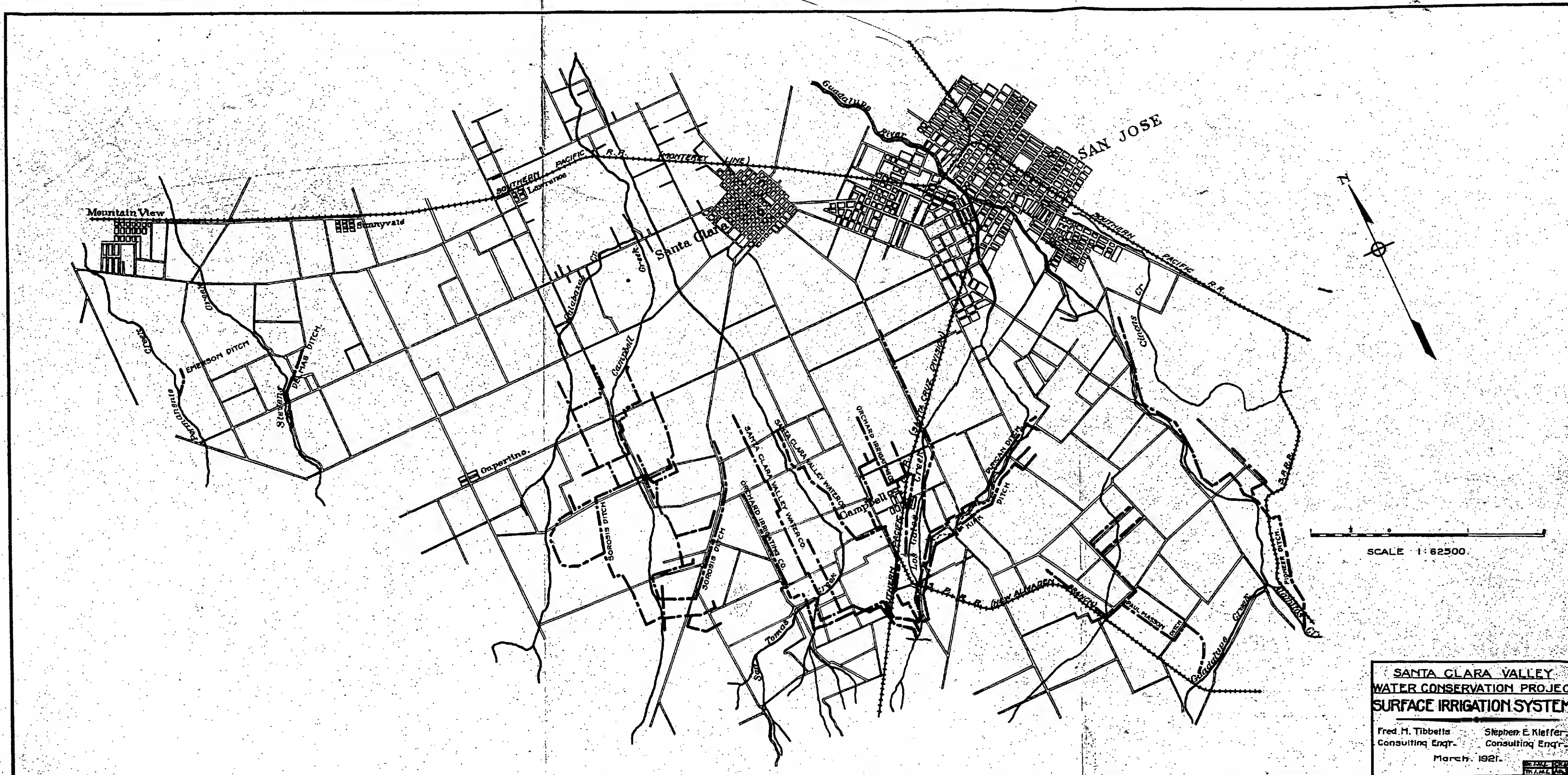

SAN JOSE
Santa Clara
Mountain View
Sunnyvale
Lawrence
Cupertino
Campbell
SOUTHERN PACIFIC R.R. (MONTEREY LINE)
SOUTHERN PACIFIC R.R.
Guadalupe River
Saratoga Creek
Calabazas Cr.
Campbell Creek
Los Gatos Creek
Stevens Creek
Permanente Creek
Coyote Creek
Canoas Cr.
Guadalupe Creek
Alamitos Cr.
San Tomas Creek
EMERSON DITCH
DEMAS DITCH
SOROSIS DITCH
SANTA CLARA VALLEY WATER CO.
ORCHARD IRRIGATING CO.
DUNCAN DITCH
KIRK DITCH
PAUL MASSON DITCH
PIONEER DITCH
S.P.R.R. (SANTA CRUZ DIVISION)
N
SCALE 1:62500.
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.
SURFACE IRRIGATION SYSTEMS
Fred. H. Tibbetts Consulting Engr.
Stephen E. Kieffer Consulting Eng'r.
March, 1921.

PLATE 6

FIG. 1. Kirk Ditch Headgate - Los Gatos Creek.

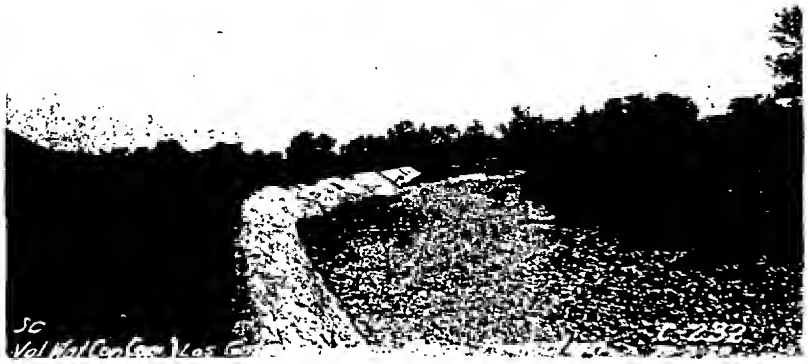


FIG. 2. Concrete Bank Protection at upper Duncan Ditch Headworks. Los Gatos Creek.

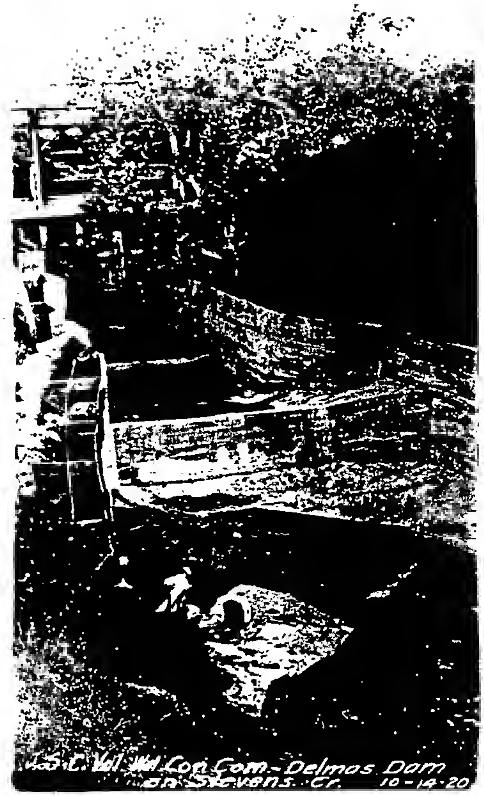


FIG. 4. Diversion Dam. Delmas Ditch. Stevens Creek.

FIG. 3. Diversion Dam - Santa Clara Valley Water Co. Los Gatos Creek.

mile above the crossing of the Southern Pacific (New Almaden Branch) Railroad. The main ditches of this system are known locally as the Duncan Ditch, with its point of diversion on the right or easterly bank (Fig. 3); the Statler Ditch, with its point of diversion on the left or westerly bank, and the Upper Duncan Ditch (Fig. 2), with its point of diversion also on the left or westerly bank. The original appropriation for the East side Duncan Ditch was made in 1882. A second appropriation was made in 1905. For the first three or four years the area irrigated gradually grew from 100 to 150 acres, reaching 500 acres in about five years. In about 1903 the Santa Clara Valley Water Company was organized and took over the Statler Ditch, whose appropriation dated from 1885. Later the upper West side Duncan Ditch was constructed to cover higher land on the West side of the Los Gatos. From 1903 to 1905 there was a rapid growth in the area irrigated under these ditches, which reached a maximum of 3500 acres. From 1905 to 1908 the area irrigated varied from year to year, depending upon the rainfall and consequent stream flow, and perhaps averaged about 1500 acres. Following the dry years of 1908 and 1910, as above discussed, a rapid decline in winter irrigation from these surface ditches took place, the area irrigated falling to as low as 150 acres. Subsequent to this time and up to the present date, the area irrigated has been relatively small, and large portions of the ditch system have badly deteriorated and rights of way have been forfeited. During the present year, interest has been somewhat revived due to the depressed level of the ground water and the acreage irrigated has been considerably increased. Water is sold by this company at varying rates, averaging about 50 cents per pound for a head of 2 to 3 second feet.

ORCHARD IRRIGATION COMPANY

The irrigation system of the Orchard Irrigation Company consists of two ditches diverting water from the Los Gatos Creek on the left or westerly bank at points about one mile and two miles above the Town of Campbell. This development was started by Mr. George Page, of Campbell, in about 1901, and ditches were rapidly extended to cover an area of about 2500 to 3000 acres. Inasmuch as the water rights for these ditches were subject to the prior rights of the other ditches above described, no water could be diverted until the needs of the other ditches were satisfied. The development of irrigation under this system met with the same fate as the other systems in the dry years of 1908 to 1910, there being only about 300 acres irrigated in 1909. Since this time very little, if any, land has been irrigated under this system. Water was sold under this ditch at the rate of 75¢ per hour for a head of two and a half cubic feet per second.

MASSON DITCH -- GUADALUPE CREEK

The Masson Ditch is a privately owned ditch system diverting water from Guadalupe Creek at a point on the left or westerly bank, immediately below the crossing of the Southern Pacific (New Almaden Branch) Railroad. The ditch system covered a maximum area of about 5000 acres, but it normally irrigated only about 800 acres per year. The amount of water diverted has been as high as four to five acre feet per acre per year.

PIONEER DITCH -- ALMADEN CREEK

The Pioneer Ditch System diverted water from Almaden Creek at a point on the right or easterly bank about ten miles South of San Jose, and about one-half mile above the junction of the Almaden and Guadalupe Creek. The ditches were owned and operated by a co-operative company of farmers

formed in 1893, and supplied water usually only to members. The maximum capacity of the ditch was about twenty-five second feet. It was used to irrigate an area varying from about 200 to a maximum of about 900 acres. The company was disincorporated in 1909 on account of conflicting water rights, dry years, and growth of pumping plants.

SOROSIS DITCH — CAMPBELL CREEK.

The Sorosis Ditch diverts water from Campbell Creek at a point on the right or easterly bank about three miles below the Town of Saratoga. It is owned and operated by the Sorosis Fruit Company. The original appropriation is said to have been made about thirty-five years ago when a dam and ditches were constructed for the purpose of diverting water. The area irrigated under this system gradually increased and reached a maximum in about 1906 of 4500 acres. The dry years of 1908 and 1910 restricted the water supply and the area irrigated, as in the case of the other ditches, the area decreasing to about 200 acres in 1912. Subsequent to 1912, and up to the present time, the area irrigated has varied from year to year, averaging about 500 to 600 acres. After the needs of the Sorosis Company are supplied, water is sold to other lands at varying rates averaging about 50 to 60 cents per hour for a head of about 4 second feet. The amount of water used under this system amounts to about two acre feet per acre gross.

DELMAS DITCH — STEVENS CREEK (Fig. 4)

This is a privately owned ditch diverting water from Stevens Creek at a point on the right or easterly bank about midway between Homestead Road and Fremont Avenue. The diversion dam (Fig. 4) and ditch were constructed in about 1904, and served a maximum area of about 1000 acres. The ditch has a capacity of about 35 second feet. The operation of this ditch system was very successful for a few years, but its service declined with

dry years till at the present time there are only about 200 or 300 acres being irrigated.

EMERSON DITCH -- PERMANENTE CREEK -

The Emerson ditch is privately owned and irrigates about 50 acres. This ditch diverts water from Permanente Creek at a point about one-half mile below Fremont Road. The diversion works were constructed about 17 years ago. Water is diverted almost continuously during periods of stream flow and is allowed to run freely over the orchard tract where it quickly sinks into the ground. The amount of water diverted varies greatly, and may amount to six acre feet per acre or more during the years when water is available. A large portion of the water passes immediately to the underground water-bearing levels, thus greatly benefitting adjacent wells.

PENITENCIA CREEK DITCHES

There are several small dams along Penetencia Creek diverting water to a relatively small acreage bordering the creek. No data is available in regard to the acreage irrigated or the amount of water used, but it is estimated that a maximum area of about 500 acres has been irrigated at the rate of about 2 acre feet per acre.

SUMMARY OF GRAVITY IRRIGATION

The following Table #2 gives a summary of the estimated acreage served by gravity ditches in Santa Clara Valley from 1903 to 1920, inclusive, together with the total amounts of water used each year. Much of the data is compiled or estimated from fragmentary or doubtful records, and no great accuracy is claimed. The maximum use of these ditches was in 1906, and they have since declined till the area served is now about one-fifth of the maximum, and less than one-half of the average for the past 18 years.

TABLE 2.

GRAVITY IRRIGATION - 1903 - 1920.

YEAR	Los Gatos Creek Ditches Ac.	Los Gatos Creek Ditches Ac.Ft.	Santa Cruz Mt.Str. N.of Los Gatos Ac.	Almaden & Guadalupe Creeks* Ac.	Total West Side Division Ac.	Total West Side Division Ac.Ft.	Peniten. Crk. & Other E. Side Strs. Ac.	Grand Total for District Ac.	Grand Total for District Ac.Ft.
1903	4,500	10,150	3,050	1,700	9,250	20,800	350	9,600	21,600
1904	5,900	13,300	3,550	1,800	11,250	25,300	480	11,730	26,400
1905	6,200	13,950	4,800	1,700	12,700	28,600	500	13,200	29,700
1906	6,200	13,950	5,550	1,900	13,650	30,700	500	14,150	31,900
1907	1,200	2,700	1,350	600	3,150	7,080	100	3,250	7,300
1908	3,200	7,200	2,850	1,600	7,650	17,200	260	7,910	17,800
1909	3,000	6,750	2,750	1,600	7,350	16,500	240	7,590	17,100
1910	2,300	5,180	2,850	1,600	6,750	15,200	180	6,930	15,600
1911	2,200	4,950	2,250	1,600	6,050	13,600	180	6,230	14,100
1912	570	1,280	450	316	1,336	3,000	45	1,381	3,110
1913	520	1,170	650	100	1,270	2,850	40	1,310	2,950
1914	2,700	6,070	1,550	200	4,450	10,000	220	4,670	10,500
1915	1,750	3,940	1,350	200	3,300	7,420	140	3,440	7,650
1916	1,250	2,810	850	300	2,400	5,400	100	2,500	5,630
1917	1,600	3,600	1,150	100	2,850	6,190	130	2,980	6,710
1918	1,100	2,470	850	100	2,050	4,600	90	2,140	4,810
1919	1,375	3,090	1,070	100	2,545	5,730	110	2,655	5,960
1920	1,475	3,320	1,070	100	2,645	5,950	120	2,765	6,230
TOTALS &	47,040	105,880	37,990	15,616	100,646	226,120	3,785	104,431	235,050
AVGE.	2,610	5,880	2,110	880	5,550	12,500	210	5,810	13,050

* Avge depth of water applied assumed in all cases at 2-1/4 ft. per season.

IRRIGATION PUMPING PLANTS

EXTENT AND DISTRIBUTION OF PUMPING PLANTS

The great bulk of the water now used for irrigation purposes in the Santa Clara Valley comes from small pumping plants. The use of water for irrigation on a large scale, seems to have started about 1897, and continued for the next ten years to increase steadily, but not rapidly, at least half of the orchards using winter irrigation from stream flow. The season of 1907-1908 was a particularly dry one, with insufficient runoff to enable the irrigation from the creeks of the extensive areas previously covered. The orchards which had been accustomed to receive winter and spring irrigation from surface ditches, suffered particularly, and this combined with widespread under-production because of drought, greatly stimulated the growth of irrigation pumping plants, so that about this time, particularly in the large orchard divisions on the West Side and along the Coyote Valley, the number of wells bored for irrigation showed a rapid annual increase. Whenever there has been a particularly dry season there has almost always been a very great increase in the number of new wells bored for irrigation, followed quite frequently by a permanent decrease in the areas desiring winter irrigation from surface streams.

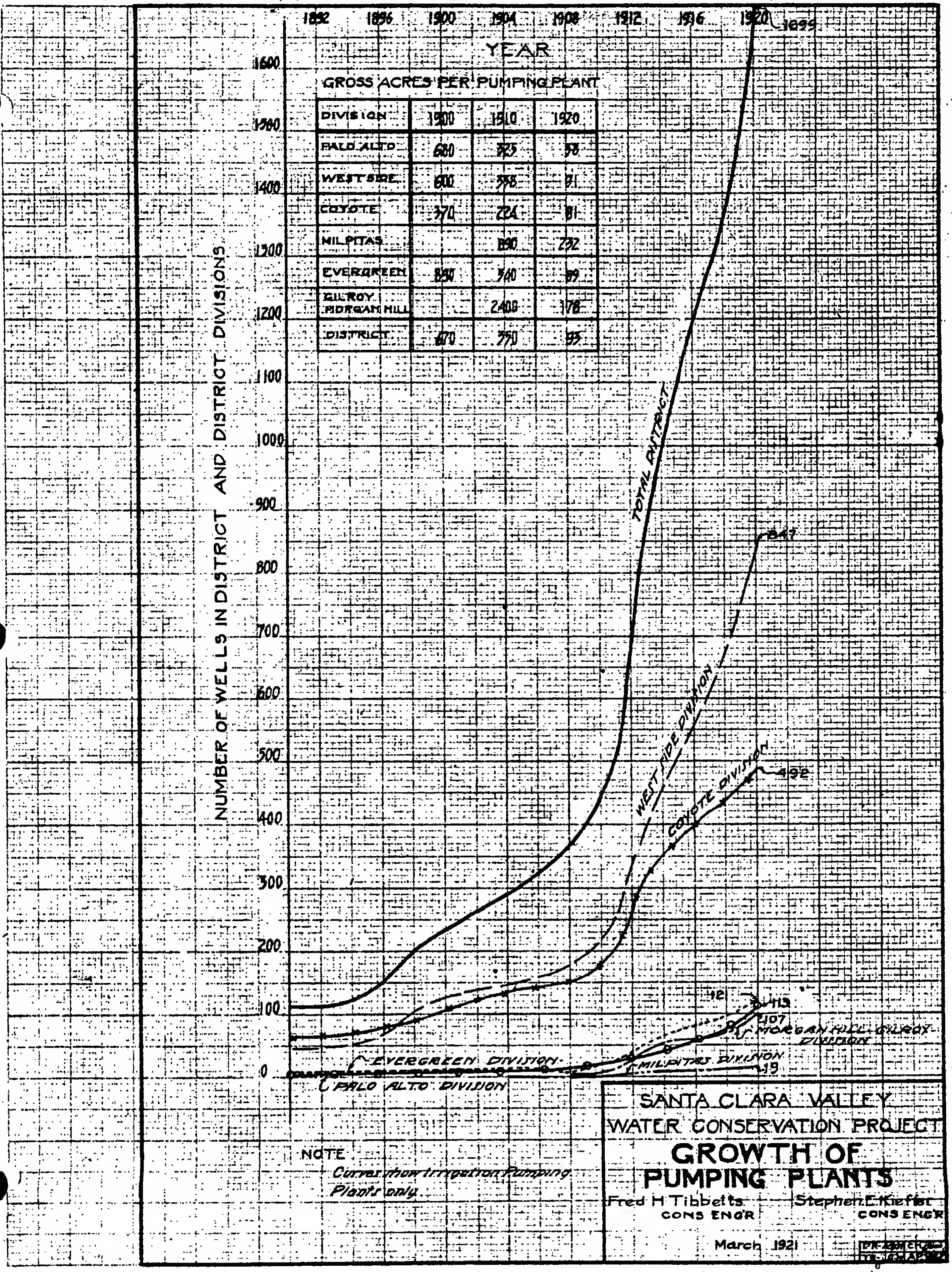
During recent years the use for irrigation of electrically driven pumping plants has been greatly stimulated by the practice of charging a minimum rate per installed Horse Power. The farmer having paid this rate in advance can do considerable irrigation at little or no charge for power. Having installed his pumping plant, and paid this minimum charge, he is also disinclined to use creek water, preferring to use his own equipment at the most favorable, or the most convenient time.

The diagrams of Plate 7 show the steady increase in the number of pumping plants installed during the last 30 years. These are plotted for the entire District, and for each of its main divisions. In the entire District at the time the census was taken, 1699 pumping plants were being used for irrigation, an average of one for each 93 acres, gross. Of this total development, 7-1/2% has occurred during the decade from 1890 to 1900, 12-1/2% from 1900 to 1910, and 73-1/2% during the last decade. Of the 73-1/2%, 21% has occurred in the last two years, making an average yearly rate for the first eight years of the decade of 6-1/2%, and for the last two years of 10-1/2%. In the Divisions of the District which are most developed as orchard sections, the distribution of pumping plants is very close to the average for the entire District.

The rate of growth, for example, of the large West Side Division during the last decade is almost exactly equal to the average for the entire District, the acreage now served per pumping plant being 91 acres, as compared with the average of 93. There are relatively more pumping plants in the Palo Alto Division, and fewer in the Gilroy-Morgan-Hill Division, and much fewer in the Milpitas Division, where except for the extreme lower portion, good wells are hard to obtain.

GOVERNMENT INVESTIGATIONS

The use of pumped water for irrigation has been investigated several times through government agencies. A report was made in 1904 by S. Fortier, Irrigation Engineer, of the Dept. of Agriculture, (Separate #2, of the Annual Report of the Irrigation and Drainage Investigations of the U. S. Dept. of Agriculture, 1904) on "Irrigation in Santa Clara Valley, California". During the preparation of this report, the cost and duty of water was determined under 60 pumping plants well distributed through



GROSS ACRES PER PUMPING PLANT

DIVISION	1900	1910	1920
PALO ALTO	680	325	58
WEST SIDE	600	558	91
COYOTE	370	224	81
MILPITAS		890	232
EVERGREEN	850	540	89
GILROY MORGAN HILL		2408	178
DISTRICT	870	550	95

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

GROWTH OF PUMPING PLANTS

Fred H Tibbetts, CONS ENG'R — Stephen E. Kieffer, CONS ENG'R

March 1921

PLATE 7

the Valley. The lift of these pumping plants ranged from 19-1/2 to 140 feet, and the discharge from .13 to 2.83 second feet. At that time nearly two-thirds of the plants tested were steam plants, and about one-third gasoline engine plants, with very few electric motors. The character of the pumping plants since that time has radically changed, so that now the greater number of plants are operated with electric motors or gasoline engines, and most of the new installations are electric.

The lifts as measured in 1904 have been carefully studied in the following chapter as an index of the drop in the water plane in the last 16 years.

Additional investigations regarding the use of pumping plants in Santa Clara Valley were made during the very dry season of 1912, the results of which are published in Office of Experiment Stations, U. S. Dept. of Agriculture, Bul. #254. Attention is particularly called in this report to"the loss involved in the wasting of from 25 to 80 per cent of the creek water in this valley".

During the preparation of this report, access has also been obtained to the original field notes of measurements made by the Irrigation Investigations of the Department of Agriculture in 1908-1909, covering costs of pumping at that time, and the extent and benefits of irrigation.

CAPACITY OF PUMPING PLANTS

Although the aggregate capacity of all the installed pumping plants has not been computed, it seems obvious that they are ample to meet the entire District's needs. The average gross acreage served per pumping plant is 93 acres. The average discharge of the 60 pumping plants tested

in 1904 was 1.39 sec. ft. If it be assumed that the average capacity of the 1700 pumping plants now in use is only 450 gallons per minute, or one second foot, or 2 acre feet per day, then they are capable of covering the entire gross area of the District 1-1/4 feet deep in about 58 days.

COSTS OF PUMPED WATER

In the Government investigations of 1904 (Page 91, Sep. #2, Annual Report), estimates were made of the costs of pumped water. The average of twenty instances cited was $1.55 per hour for 1.44 sec. ft. This was the average price paid by orchardists who bought water from the pumping plants of an adjoining orchard. The rates charged per hour varied from about $1.00 to $2.50. The average cost to the buyer of water at that time (1904) as computed from the above figures was $13.00 per acre foot. The actual operating cost when the pumping plants were tested was $.066 per ft. acre ft., or $4.38 per acre ft., the average lift being 66 feet. Fixed charges were estimated at $5.20 per acre irrigated, this increasing the average cost to the owner, to $10.16 per acre, or $9.00 per acre foot.

In the government report of 1912, it is stated that in about half of the cases observed, the lift was between 70 and 85 feet, and the actual operating costs per acre foot between $4.92 and $8.33. It is also stated that many orchardists not having their own pumping plants, purchased pumped water, sometimes at a cost as much as $20.00 per acre foot.

Since 1904-1912, operating costs, as well as installation costs of pumping machinery, have greatly increased. A careful study of the original notes of the 1904 Government Investigations shows that at that time fuel oil in Santa Clara Valley cost from 80¢ to 85¢ per bbl., or approximately 40% of last season's price. Engineers for the operation

of steam or gasoline plants were generally being paid $2.50 or $3.00 per day, this probably representing from 40% to 50% of present prices for such labor. Distillate cost about 10-1/2¢ per gallon, and probably was about the equivalent of the product now sold as gasoline. The bulk of the pumping plants are now operated by electric motors, and require less attendance than the steam plants in general use in 1904. The cost of power, however, particularly if the minimum installed Horse Power charges are considered in the years in which but little use is made of the pumping plants, would probably be equivalent to the cost of steam power generated with oil, costing at least $2.00 to $3.00 per barrel. The cost of machinery and of the labor for boring wells and for installing machinery will also be about two to two and one-half times the costs of 1904.

A consideration of all the above data will indicate that present operating costs are at least double those of 1904. The average lift has also increased due to receding water levels, particularly in the last five years. On the basis of the 1904 figures then, it would seem that the average costs to the pump owner, including fixed charges, are probably in the neighborhood of $20.00 per acre foot, or say $25.00 per acre, if 1-1/4 ft. in depth of water be applied, this being the depth assumed in this report as most desirable.

Water, of course, costs more to the majority of orchardists who purchase water from neighboring pumping plants. Present rates to the buyer are from $2.00 to $3.50 per hour. If the average discharge be assumed as 1 sec. ft., or 450 gallons per minute (this being the net amount that the buyers receive after losses in transit from seepage and evaporation) and the average rate per hour be assumed at $2.50, then the average cost per acre foot to the buyer would be $30.00, and for 1-1/4 foot in depth, would be $37.50. The above figures may be materially in-

creased under unfavorable conditions of small pumping streams, especially if transmitted for considerable distances, over porous soils. All of these figures may also be indefinitely increased if the water plane continues to recede, this recession adding to the operating costs for power, and materially increasing the fixed charges because of either increased first cost of installation or of increased reconstruction costs, for the deepened wells and lowered pumps which would be required.

EXTENT AND DEVELOPMENT OF IRRIGATION

IRRIGATION DEVELOPMENT TO 1920

The total amount of water required for the full agricultural development of Santa Clara Valley is dependent upon the areas of various crops to be served, and upon the assumed duty of water.

The areas which are now being irrigated have been considered and classified according to crops in the previous Chapter 2. A summary of the land and crop classification indicates a total net irrigated agricultural area in 1920 of 86,042 acres, and an additional net irrigable area of 41,170 acres, or a total net irrigable area of 127,212 acres. In addition, the non-agricultural areas classified as swamps, and cities and towns, are using, or will eventually require their portion of the available water supply.

The following Table 3 shows classification of the irrigable, and the 1920 irrigated areas in the valley summarized by divisions and by crop census classifications. Slightly over two-thirds of the irrigable agricultural lands were served with water in 1920, this two-thirds including 90-1/2% of the orchard area, all of the truck gardening, alfalfa, etc., but none of the vineyards, or grain and hay land. The divisions in which there is the greatest proportion of developed orchard and truck gardening, also

indicate the greatest proportionate development of irrigated demand.

TABLE 3.

CLASSIFICATION OF NET POSSIBLE WATER USING AREAS 1920.

CLASSIFICATION	PALO ALTO	WEST SIDE	COYOTE	MILPITAS	EVER GREEN	MORGAN HILL GILROY	TOTAL DISTRICT
Orchards	847	41,866	12,995	350	5,712	9,755	71,525
Vineyards	-	1,261	357	-	23	1,269	2,910
Truck & Berries,	1221	3,961	2,840	1,692	343	526	10,583
Alfalfa and Sugar Beets,	396	3,609	5,539	171	390	412	10,517
Grain and Hay,	2034	12,223	8,026	1,723	2,854	4,817	31,677
Total Agricultural Area,	4498	62,920	29,757	3,936	9,322	16,779	127,212
Cities & Towns,	1409	5,461	3,275	9	-	127	10,281
Swamps	-	-	-	-	250	-	250
Total	5907	68,381	33,032	3,945	9,572	16,906	137,743
Agricultural Area Irrigated 1920	2260	46,193	20,474	2,213	4,942	9,960	86,042
% Irrigated 1920	50½	73½	69	56½	53	59½	67½

DUTY OF WATER

The water requirements of any irrigated area depend upon a great variety of factors, such as soil types, amount and distribution of rainfall, winds, temperature, and to a great extent upon the kind of crops to be raised.

AGRICULTURAL AREAS

Approximately 75% of the total net irrigated agricultural area of the District is in orchard of various kinds. The actual amounts of water for orchard irrigation in Santa Clara Valley which will give the most beneficial results, will vary widely with the kind of trees, methods of cultivation, and especially with the character of the soil and sub-soil, and the normal position of the water plane. Much study has been given to this matter by State and Government authorities, and experimental work is now under way under the auspices of the United States Department of Agriculture, to determine the amounts of water which will insure the greatest yield of orchard crops.

Measurements of the duty of water under 60 different pumping plants well distributed over Santa Clara Valley, were made in 1904. (Annual Report Irrigation and Drainage Investigations, U. S. Dept. of Agriculture, Separate #2, Page 89). The total annual depth of water varied from .16 ft. to 4.70 ft., and averaged for 2272 acres, 1.13 ft., the average lift being 66 feet.

For the purpose of this report, it will be more or less arbitrarily assumed that for the average orchard crop, cultivation methods, and soil conditions over the extensive and widely varying area included within the proposed District, the duty of water will be 1-1/4 ft. per year for the net areas in orchard. For other irrigated crops,

such as truck gardening, berries, alfalfa, sugar beets, etc., the total forming less than 1/4 of the irrigated area, it will be assumed that the annual requirement for water is 2 acre feet per acre.

URBAN AREAS

Within the District are the incorporated cities of San Jose, Palo Alto, Santa Clara, Mayfield, Mountain View, Sunnyvale, and Morgan Hill, with a total area, including the outlying suburban territory of 10,281 acres. The total population in this area is estimated at about 80,000, and the total average water consumption at 12 million gallons per day, or a total of 4400 million gallons, or 13,450 acre feet per year. Dividing this aggregate quantity of municipally used water by the total urban area of 10,281 acres gives a fairly close estimate of the actual duty of water for the gross area in the cities and towns as 1.31 acre feet per acre per year. This estimate is believed to be fairly close as actual records of water consumption were obtained from the principal water companies supplying the various municipalities. The average per capita consumption of 150 gallons is quite normal, and the general conclusion has been previously reached in Southern California that the spread of urban development in orchard territory does not necessarily mean a materially increased water requirement.

WATER REQUIREMENTS

WATER FOR 1920 SEASON

A reclassification and summary of the 1920 water using areas combined with the duty of water as above deduced, gives the total amount of water which should have been developed and used in the District for 1920. The following Table 4 shows that the orchard areas should have used 81,200 acre feet, or about 60% of the total, the entire agricultural areas, 123,420 acre feet, or about 90%, and the cities and towns, 13,450 acre feet, or about 10% of the grand total of 136,870 acre feet.

TABLE 4.

WATER NEEDS FOR NET AREAS IRRIGATED IN 1920.

USE	AREA (ACRES)	ASSUMED DUTY	TOTAL WATER REQUIRED	REMARKS
Orchards	64,942	1.25 ac.ft. Pr.Ac.	81,200 Ac.Ft.	Net Area
Truck & Berries,	10,583	2.00 " " " "	21,180 " "	" "
Alfalfa, Sugar Beets, Etc.	10,517	2.00 " " " "	21,040 " "	" "
Total Crops	86,042		123,420 " "	
Cities & Towns,	10,281	1.31 " " " "	13,450 " "	Gross Area
Total or Average,	96,323	1.42 " " " "	136,870 " "	

ULTIMATE WATER REQUIREMENTS

Time of Maximum Demand: As previously shown, there is a total net area of irrigable agricultural land in the proposed District of 127,212 acres, of which there was irrigated in 1920, 86,042, or 67½%, and irrigable but not irrigated, 41,170 acres, or 32½%.

A government publication (Office of Experiment Stations, Department of Agriculture, Bulletin #254, Pg. 23) in 1912, classified the total agricultural land in the valley as 148,000 acres, of which 42,550 acres is given as irrigated; a total of about 29%. This indicates an increase in the percentage of irrigable land which is irrigated, during the last 8 years, of from 29% to 67½%, or a total of 38½% increase. If the same proportionate percentage increase were continued, the balance of the irrigable land would be irrigated within about 6 years. This is about half of the time apparently indicated by the studies of Chapter 2, and by Plate 5, as required for the completion of orchard development. It is evident that full irrigation demand will not occur until essentially all of the remaining agricultural land is in orchard, truck gardening, alfalfa or other irrigated crops.

It is the writer's best judgment based on available data, that within 10 years the maximum demand for water will be reached and will then be steadily sustained and practically uniform and that within that period essentially all of the total area in the proposed district of 157,550 acres would use water were it available, with the exception of the 10% deductions in the agricultural areas for roads, buildings, etc.,

and the areas classified as hills and creeks.

<u>Amount of Maximum Demand:</u> Above the areas within the limits of the boundary lines of the District as drawn, there are marginal areas which will desire more water than the natural rainfall. For the portion of the total District from the Lower Gorge of the Coyote River northward, aggregating 130,439 acres, it will be assumed that such high marginal areas increase the area requiring water by about 5%. The same assumption will be made for the southern or Morgan Hill-Gilroy Division, it being assumed that the water plane in the area south of Gilroy, is normally so close to the surface that there will be no demand for supplying this area with additional water.

As previously deduced for the entire District (See Table 3) the irrigable area in 1920 was 32½% undeveloped. If the water requirement of the proposed District is also 32½% undeveloped, then the water demand will increase within the next decade from the 136,870 acre feet of 1920 to a sustained maximum of about 203,000 acre feet per year.

If allowance be made for the marginal lands outside the District this will be increased to 213,000 acre feet per year.

CHAPTER IV

WATER RESOURCES

GENERAL WATER SUPPLY CONDITIONS

The source of the water supply of the Santa Clara Valley is the drainage, generally designated as "run off", from the slopes or watershed of the immediately surrounding mountains.

All that portion of the valley north of the Upper Gorge of the Coyote (near Morgan Hill) and comprising about 88% of the total area, drains northward into the Bay of San Francisco, and is fed by the drainage of approximately 87% of the tributary watershed. From Morgan Hill the slope of the valley is southward to Gilroy, this portion containing about 12% of the total valley area and being fed by 13% of the total tributary watershed.

The water entering the valley margins has in the past for the most part been allowed to find its way naturally down the stream channels, replenishing annually as far as nature would permit the underground water supply, or storage, and the balance not thus stored, and made available for use through the agency of pumping plants, has escaped. For many years a small and varying amount of water has been diverted by means of surface ditches from some of the streams during the period of winter and spring flow.

Until quite recently the volume of water thus annually, and very irregularly, conserved by nature in this manner has sufficed to maintain in a general way the underground water table at a fairly constant, or normal, elevation after taking into account the usual seasonal fluctuations. In a situation like the Santa Clara Valley this normal level of the water table is a relative matter and the standard of measurement as to its "normality" depends upon whether, under a given amount of use to support a given development, it maintains a constant, though variable, average, with no gradual and persistent decline. With each new stage of development, and its corresponding demand for irrigation water, a new and lower level of the water table obtains, until that point is reached where under maximum development of the land and its reasonable demand for water there is no further permanent decline, and not until this stage has been reached, or assured within prescribed limits, can stability of the water supply, and the development values dependent upon the same, be assured.

The early records of Santa Clara Valley show it to have been a plentifully watered region, with perenial streams and a water table everywhere close to the ground surface. Obtaining water from surface wells was a simple matter. For many years during the earlier development of the valley, and up until recent years, the water supply from wells was abundant and there was no serious lowering of the water table, which remained fairly constant under the draft made upon it, indicating that the natural replenishment was reasonably adequate. The

occasionally recurring years of serious drouth were not particularly marked in their effect upon the limited volume of water pumped from underground storage. Gradually, however, with the increased demand for irrigation on existing and new orchards, and the great increase of annual field crops, the effect of pumping became more marked upon the lowering water table. Artesian wells in the low portion of the valley ceased to flow, and where suction pumps were used on the higher ground they had to be steadily lowered in pits and eventually give way to deep well pumps.

The dry years of 1912-1913, while no worse than similar years in the past, were very marked in their effect upon ground water levels, and were severely felt. With the advent of the world war, and the resulting greatly increased demand for products of the soil, culminating in the heavy demand years of 1917 to 1920, the draft upon the underground water resources of the valley was unprecedented. Coincident with this period of heavy planting and crop production, and water demand, came the dry years of 1918 and 1920, with practically no recovery of the water table from underground water replenishment during the year 1919. The combination of a permanently increased and increasing demand for water with several years of less than normal replenishment, has sharply accentuated the drop of the water table and taken it to new and unprecedented low levels. The point has been reached where the present

demand is in excess of natural underground replenishment, and the water table must continue to drop unless irrigation is decreased, or the supply of water increased.

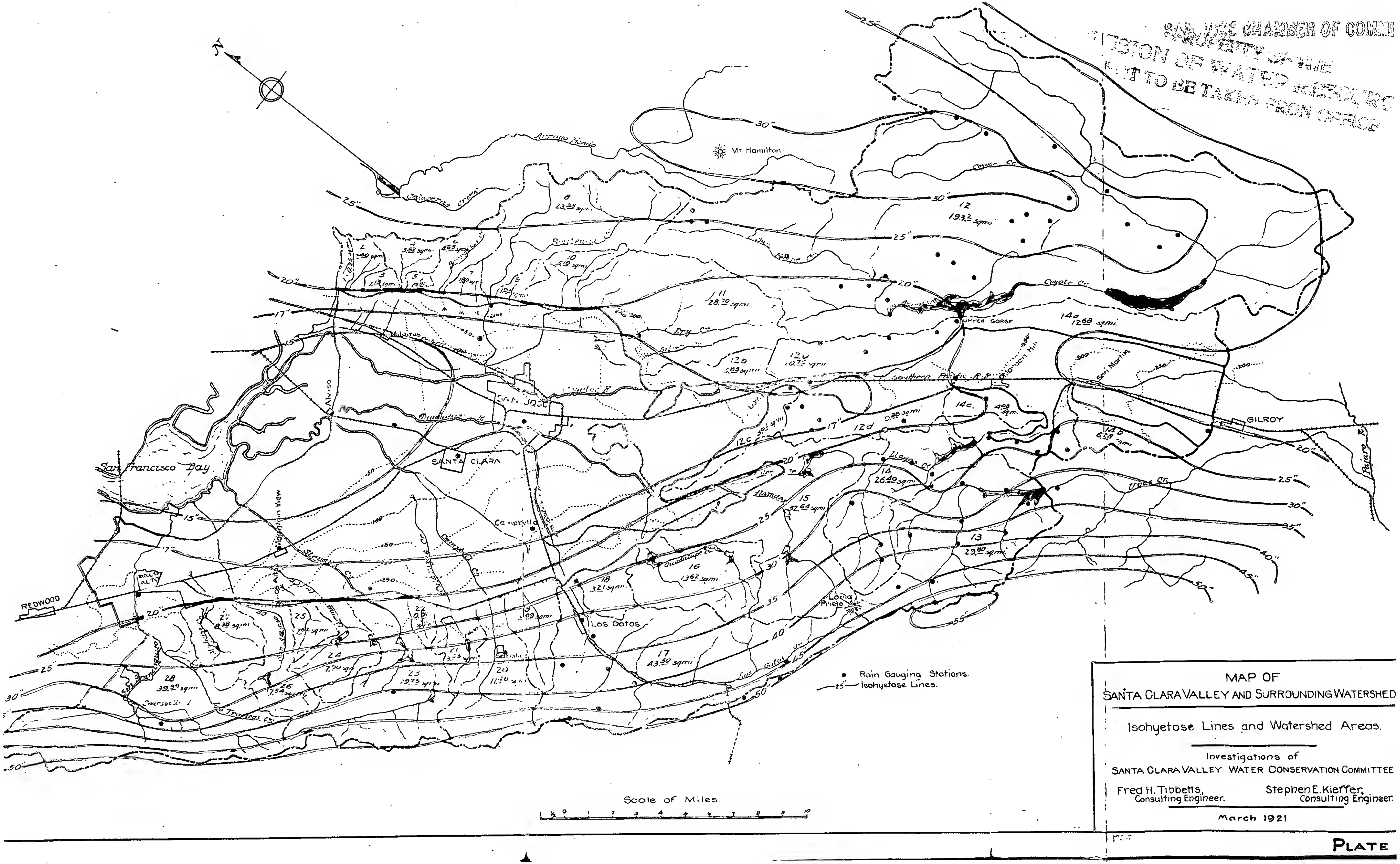
TRIBUTARY WATERSHEDS

The tributary watersheds of the valley are indicated upon the accompanying general map. (Plate 8) The total area, as computed from the maps of the U.S.G.S., is 576.7 square miles. Of this total 497.4 square miles drain into San Francisco Bay, and 79.3 square miles drain south toward Gilroy and Monterey Bay. The largest single drainage area is that of Coyote Creek, with 193.2 square miles, and from this the various independent areas range downward in size to less than one square mile. The maximum elevation on the eastern watershed is reached at Mt. Hamilton (4209 ft.) at the head of the Coyote Creek drainage area, and on the western watershed at Mt. Loma Prieta (3806 ft.) at the head of the Uvas, Llagas, Alamitos and Los Gatos Creeks drainage areas.

The topography of the watersheds is for the most part steep and rugged, and well covered with brush and timber. The slopes on the west are much more densely forested than those on the east, coniferous trees largely prevailing. The eastern slopes are more open, with grass and brush cover and scattered tree growth, mostly oak.

For the purposes of detailed study the total watershed area has been segregated into twenty-eight parts, each having a separate drainage outlet upon the valley floor. These are shown upon the watershed map. (Plate 8).

The regional distribution of these areas is shown in the following table 5:-



MAP OF
SANTA CLARA VALLEY AND SURROUNDING WATERSHED
Isohyetose Lines and Watershed Areas.
Investigations of
SANTA CLARA VALLEY WATER CONSERVATION COMMITTEE
Fred H. Tibbetts, Consulting Engineer. Stephen E. Kieffer, Consulting Engineer.
March 1921
PLATE

Table 5

REGIONAL DISTRIBUTION OF TRIBUTARY WATERSHEDS

Section	Tributary Watershed Square Miles Each	Tributary Watershed Square Miles Total	Percent of Total
East Side-Milpitas to Lower Gorge of Coyote (11 drainage areas)		74.47	12.9
South Side			
Coyote-above upper Gorge	193.20		
Coyote-below upper Gorge	25.98		
Alamitos	32.64		
Guadalupe	13.62		
Miscel. (2 areas)	6.83	272.27	47.3
West Side			
Los Gatos	43.50		
San Tomas	5.09		
Campbell	11.48		
Calabazas	3.53		
Stevens	19.75		
Permanente	7.90		
San Antonio	7.54		
Madera	8.38		
San Francisquito	39.99		
Miscel. (2 areas)	3.53	150.69	26.1
South Side			
Uvas	29.80		
Llagas	26.40		
Miscel. (valley margins)	23.04	79.24	13.7
Total		576.67	100.

RAINFALL

GENERAL

As a basis for computing the estimated run-off of water from the watersheds it has been necessary to determine with the greatest degree of accuracy possible the average annual rainfall over each separate watershed. In order to ascertain the probable average distribution of rainfall all available public and private rainfall records were obtained. These records have been referred to San Francisco (1849-1920) as the primary base station for interpolations and expansions where required.

Eight secondary base stations were taken within or adjacent to the area as follows:-

Mt. Hamilton (1881-1920), Gilroy (1874-1915), San Jose (1874-1920), Los Gatos, (1885-1920), Campbell (1897-1920), Mountain View (1885-1920), Permanente (1871-1920), and Calaveras (1874-1920).

The records of these stations were interpolated and expanded to the San Francisco base by comparing their mean record with the mean of San Francisco for a corresponding period of time.

Upon the mean of the eight secondary base stations thus established, the partial rainfall records of all other stations were in a similar manner expanded for the 71 year period. From the files of the former Bay Cities Water Company there were made available records from 93 rain gage stations, observed between the years 1902-1909, on the watershed areas of Coyote Creek and the Mt. Hamilton region, and Uvas and Llagas Creeks. From miscellaneous public and private sources records of varying length were obtained at thirty-one additional stations. The following Table 6 gives the observed and estimated rainfall at the base and principal subsidiary stations for each year of the 71 year period from 1849-1920. The rainfall year is taken from Sept. 1st, to August 31st.

TABLE 6.

SEASONAL RAINFALL IN INCHES AT BASE STATIONS

(Rainfall year from September to August)

Rainfall Year Sept. Aug.	Gilroy	Mt. Hamilton	San Jose	Los Gatos	Campbell	Mountain View	Permanente	Calaveras	San Francisco
1849-50	(29.91)	(45.31)	(22.85)	(48.39)	(23.96)	(22.58)	(32.75)	(37.40)	33.10
50-51	(6.72)	(10.19)	(5.14)	(10.88)	(5.39)	(5.08)	(7.59)	(8.41)	7.44
51-52	(16.66)	(25.24)	(12.73)	(26.96)	(13.35)	(12.58)	(18.82)	(20.83)	18.44
52-53	(31.89)	(48.33)	(24.37)	(51.60)	(25.55)	(24.08)	(36.02)	(39.88)	35.30
53-54	(21.54)	(32.64)	(16.46)	(34.85)	(17.26)	(16.27)	(24.33)	(26.94)	23.84
54-55	(21.46)	(32.51)	(16.40)	(34.72)	(17.19)	(16.20)	(24.24)	(26.83)	23.75
55-56	(19.59)	(29.68)	(14.97)	(31.69)	(15.69)	(14.79)	(22.12)	(24.50)	21.68
56-57	(18.02)	(27.30)	(13.77)	(29.15)	(14.43)	(13.60)	(20.35)	(22.53)	19.94
57-58	(19.85)	(30.08)	(15.17)	(32.12)	(15.90)	(14.99)	(22.42)	(24.82)	21.97
58-59	(19.90)	(30.16)	(15.21)	(32.20)	(15.95)	(15.03)	(22.48)	(24.89)	22.03
59-60	(20.29)	(30.75)	(15.51)	(32.43)	(16.26)	(15.32)	(16.31)	(25.38)	22.46
1860-61	(17.63)	(26.71)	(13.47)	(28.52)	(14.12)	(13.31)	(16.69)	(22.04)	19.51
61-62	(44.52)	(67.45)	(34.02)	(72.02)	(35.66)	(33.62)	37.73	(55.67)	49.27
62-63	(12.41)	(18.81)	(9.49)	(20.09)	(9.95)	(9.37)	9.38	(15.52)	13.74
63-64	(9.30)	(14.09)	(7.10)	(15.04)	(7.45)	(7.02)	7.56	(11.63)	10.29
64-65	(22.15)	(33.51)	(16.93)	(35.84)	(17.75)	(16.73)	10.50	(27.70)	24.52
65-66	(20.72)	(31.39)	(15.83)	(33.52)	(16.60)	(15.64)	24.75	(25.91)	22.93
66-67	(31.55)	(47.71)	(24.11)	(51.05)	(25.28)	(23.82)	21.38	(39.45)	34.92
67-68	(35.09)	(53.17)	(26.81)	(56.78)	(28.11)	(26.50)	34.94	(43.88)	38.84
68-69	(19.29)	(29.23)	(14.74)	(31.21)	(15.45)	(14.51)	17.50	(24.12)	21.35
69-70	(17.46)	(26.44)	(13.33)	(28.23)	(13.98)	(13.17)	10.87	(21.82)	19.31
1870-71	(12.77)	(19.34)	(9.76)	(20.66)	(10.23)	(9.64)	12.94	(15.96)	14.13
71-72	(27.80)	(42.12)	(21.20)	(44.98)	(22.27)	(20.00)	35.53	(34.77)	30.77
72-73	(14.22)	(21.55)	(10.87)	(23.01)	(11.39)	(10.74)	16.25	(17.78)	15.74
73-74	(22.26)	(33.73)	(17.01)	(36.02)	(17.83)	(16.81)	22.94	(27.84)	24.64
74-75	(15.12)	(15.66)	7.90	(16.73)	(8.28)	(7.81)	13.72	16.28	20.56
75-76	(31.04)	(38.60)	19.47	(41.23)	(20.42)	(19.26)	35.26	40.50	31.21
76-77	6.53	(9.58)	4.83	(10.22)	(5.07)	(4. 78)	8.94	12.15	11.04
77-78	28.03	(38.22)	19.28	(40.83)	(20.22)	(19.07)	37.84	29.02	35.17
78-79	16.76	(32.51)	16.40	(34.73)	(17.20)	(16.22)	17.50	21.43	24.46
79-80	22.38	(27.30)	13.77	(29.16)	(14.44)	(13.62)	28.13	27.69	26.63
80-81	23.43	(24.68)	12.45	(26.37)	(13.06)	(12.31)	24.94	25.03	29.86
81-82	14.09	29.15	11.75	(24.88)	(12.32)	(11.62)	16.69	22.32	16.14
82-83	15.19	37.26	10.59	(22.43)	(11.11)	(10.47)	18.75	21.40	20.12
83-84	24.60	58.24	20.08	(42.53)	(21.06)	(19.86)	32.56	37.26	32.42
84-85	14.90	44.52	11.27	(23.87)	(11.82)	(11.15)	19.25	19.63	18.12
85-86	21.29	31.42	20.66	43.06	(21.67)	16.92	29.80	31.66	33.22
86-87	11.11	24.12	11.35	24.32	(11.90)	10.14	18.31	(18.57)	18.82
87-88	16.78	30.01	12.15	24.17	(12.74)	12.38	16.46	(19.88)	16.75
88-89	14.44	21.83	15.71	29.87	(16.47)	16.73	18.27	19.87	23.85

TABLE 6. - Con.

SEASONAL RAINFALL IN INCHES AT BASE STATIONS

(Rainfall year from September to August)

Rainfall Year Sept. Aug.	Gilroy	Mt. Hamilton	San Jose	Los Gatos	Campbell	Mountain View	Permanente	Calaveras	San Francisco
89-90	37.75	45.16	30.30	67.22	(31.77)	31.15	41.14	45.54	45.86
1890-91	14.84	24.05	12.88	31.97	(13.51)	14.00	22.57	20.23	17.68
91-92	18.91	27.49	16.51	23.11	(17.31)	12.61	18.58	25.24	18.41
92-93	24.50	37.93	25.17	56.24	(26.39)	27.76	45.38	39.20	21.77
93-94	12.91	35.86	12.92	21.25	(13.55)	11.94	20.95	30.81	18.45
94-95	28.81	36.60	23.32	47.18	(24.45)	22.36	36.80	38.63	25.71
95-96	25.70	30.03	14.44	35.25	(15.15)	13.53	25.44	25.82	21.37
96-97	20.82	31.94	15.81	31.72	(16.58)	19.34	23.63	31.20	23.31
97-98	10.44	17.66	6.87	15.18	8.20	7.12	11.51	13.37	9.38
98-99	19.44	25.85	10.02	24.93	13.17	12.26	17.81	20.98	16.87
99-00	14.54	29.22	13.89	24.24	12.29	12.26	18.57	25.84	18.47
1900-01	23.17	31.66	19.86	41.35	21.30	16.52	26.95	30.66	21.17
01-02	18.41	27.57	12.98	33.23	13.91	11.56	22.64	28.27	18.98
02-03	17.48	30.29	13.89	28.98	15.74	13.43	22.45	24.95	18.28
03-04	18.26	33.82	10.72	29.82	12.73	10.58	20.01	27.49	20.67
04-05	23.25	28.50	17.71	35.31	20.50	17.25	26.21	28.72	23.37
05-06	29.42	38.43	15.12	38.13	17.51	16.38	28.32	28.04	20.61
06-07	28.98	43.34	22.71	43.42	23.38	20.86	35.62	32.98	26.00
07-08	14.25	23.92	11.69	22.38	12.46	14.11	18.45	17.34	17.36
08-09	27.81	37.42	18.31	44.75	18.52	19.49	37.44	(29.96)	25.54
09-10	19.47	26.06	14.52	25.78	12.51	14.75	19.19	(23.76)	19.52
1910-11	19.41	33.25	22.65	52.53	21.89	22.66	35.46	28.12	25.49
11-12	13.87	18.24	10.58	19.46	10.74	10.78	14.95	14.79	14.06
12-13	10.49	18.04	6.52	15.73	5.47	6.04	11.14	13.21	12.05
13-14	32.96	35.45	19.28	52.78	19.69	18.89	34.64	23.73	29.54
14-15	21.22	27.75	22.30	36.81	21.93	23.96	33.51	30.97	27.40
15-16	(21.31)	29.60	16.28	38.53	17.87	16.62	20.24	19.47	27.43
16-17	(16.52)	24.46	12.62	29.29	12.58	10.10	21.39	14.07	15.46
17-18	(12.25)	15.66	9.36	14.53	7.39	8.51	11.07	10.17	11.48
18-19	(24.73)	27.40	18.90	34.55	22.44	19.10	27.76	21.54	25.65
19-20	(11.52)	21.50	8.80	20.55	9.62	8.73	15.26	13.78	10.45
Mean	20.31	30.77	15.52	32.85	16.27	15.34	22.93	25.40	22.48

Note:- Parentheses indicate interpolations from San Francisco Base.

Based upon the mean of the base stations shown in the above Table 6, available rainfall records have been extended for the 71 year period of the San Francisco base at the following subsidiary stations, and their normal rainfall for that period determined.

TABLE 7.

SUBSIDIARY RAINFALL STATIONS AND ESTIMATED NORMAL RAINFALL

Name of Station	Normal Rainfall, 71 yrs. Inches
Mean of Primary Base (S.F.)	22.48
" Secondary Bases	22.44
Palo Alto	19.56
Damsite on Stevens Creek	19.83
Monte Bello Ridge	40.29
Homestead Road (Meyerholtz)	19.23
Crystal Springs Cottage	30.56
Searsville Lake-Portola	30.60
San Andreas	41.97
Wrights	45.09
New Almaden Sta.	22.43
Woodside	34.29
Pilarcitos	50.84
Berryessa	15.78
Santa Clara	16.41
Uvas Canyon (Eastman)	34.51
Llagas " (Paradise Valley)	28.02
Coyote #5	30.23
Williams Res.	43.44
Saratoga	33.69
Howell Res.	41.39
Ousley	37.26
Tisdale	31.23
Seven Mile	22.81
Morrell	47.71
Bullock	50.68
Evergreen	17.07
Coyote	19.34
Morgan Hill	23.57
Agnew	14.14
Alma	39.66
Griffin Ranch (Los Altos)	21.78

DISTRIBUTION OF NORMAL RAINFALL

The distribution of the rainfall stations referred to above is indicated upon the accompanying general watershed map. (Plate 8) Upon this map, based upon the 71 year normal rainfall of the various stations, there have been drawn isohyetose lines, or lines of equal normal rainfall. Where rainfall stations are lacking these lines have been project with relation to existing stations, giving due consideration to the influence of the intermediate topography upon probable rainfall conditions.

The normal mean rainfall for each segregated watershed of the combined total watershed was determined by dividing the cubical quantity of precipitation over any given area (ascertained by planimetering the area on the map and securing mean depth from the isohyetose lines) by the area of the watershed.

The normal rainfall thus obtained for each of the watershed areas is shown in the following Table 8:-

TABLE 8.

DISTRIBUTED NORMAL RAINFALL

Watershed Area Number	Name	Area Square Miles	Normal Rainfall Inches
1	Scott	.95	21.50
2	Calera	2.40	22.50
3		1.15	21.00
4	Los Coches	5.52	23.00
5		.92	21.00
6	Berryessa	4.65	24.40
7		1.80	21.50
8	Penitência	23.35	25.10
9		1.93	21.50
10		5.10	22.00
11	Evergreen	28.70	19.40
12	Coyote	193.20	24.82
12a	"	10.75	18.00
12b	"	5.85	17.20
12c	"	3.62	17.50
12d	"	9.38	18.00
13	Uvas	29.80	38.00
14	Llagas	26.40	27.80
14a		12.68	21.00
14b		6.28	25.00
14c		4.08	20.00
15	Alamitos	32.64	27.40
16	Guadalupe	13.62	28.70
17	Los Gatos	43.50	40.70
18		3.21	27.40
19	San Tomas	5.09	31.60
20	Campbell	11.48	43.30
21	Calabazas	3.53	33.40
22		.91	22.00
23	Stevens	19.75	40.50
24	Permanente	7.90	29.80
25		2.62	23.30
26	San Antonio	7.54	29.30
27	Madera	8.38	23.10
28	San Francisquito	39.99	36.70
		576.67	

The normal rainfall over the valley floor proper is as follows:-

Main Valley, Lower Gorge to Bay	16.47 inches
Almaden Valley	21.00 "
Coyote-Gilroy Valley, Lower Gorge to Gilroy	19.72 "

DISTRIBUTED ANNUAL RAINFALL

Based upon the distributed normal rainfall shown in Table 7 the estimated mean annual rainfall in inches depth for each of the segregated watersheds is shown for the 18 year period from 1902-1920 in the following Table 9.

TABLE 9.
DISTRIBUTED MEAN ANNUAL RAINFALL

Season	Watershed Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1902-3	20.	21.	19.6	21.4	19.6	22.7	20.	23.4	20.	20.5	18.1	23.6	33.5	24.6
3-4	19.6	20.5	19.1	20.9	19.1	22.2	19.6	22.9	19.6	20.	17.7	20.4	36.8	27.
4-5	23.6	24.7	23.1	25.3	23.1	26.8	23.6	27.6	23.6	24.2	21.3	26.6	41.3	30.4
5-6	25.3	26.5	24.7	27.1	24.7	28.7	25.3	29.6	25.3	25.9	22.8	30.8	47.	34.5
6-7	30.1	31.5	29.4	32.2	29.4	34.2	30.1	35.1	30.1	30.8	27.2	36.4	50.8	37.3
7-8	16.1	16.9	15.7	17.2	15.7	18.3	16.1	18.8	16.1	16.5	14.5	19.	28.2	20.7
8-9	28.	29.3	27.3	29.9	27.3	31.8	28.	32.7	28.	28.6	25.3	31.3	51.	37.4
9-10	18.7	19.6	18.2	20.	18.2	21.2	16.7	21.8	18.7	19.1	16.9	21.8	33.6	24.7
1910-11	28.3	29.6	27.6	30.2	27.6	32.1	28.3	33.	28.3	28.9	25.5	30.9	45.6	33.5
11-12	13.6	14.2	13.3	14.5	13.3	15.4	13.6	15.9	13.6	13.9	12.3	16.1	24.4	17.9
12-13	10.4	10.9	10.1	11.1	10.1	11.8	10.4	12.1	10.4	10.6	9.4	12.6	19.1	14.
13-14	28.4	29.8	27.8	30.4	27.8	32.3	28.4	33.2	28.4	29.1	25.7	33.9	59.5	43.6
14-15	26.2	27.4	25.6	28.	25.6	29.7	26.2	30.5	26.2	26.8	23.6	29.9	46.3	33.9
15-16	21.5	22.6	21.	23.1	21.	24.5	21.5	25.2	21.5	22.	19.4	24.6	38.1	27.9
16-17	16.9	17.7	16.5	18.1	16.5	19.2	16.9	19.7	16.9	17.3	15.2	19.3	29.9	21.9
17-18	10.7	11.1	10.4	11.4	10.4	12.1	10.7	12.4	10.7	10.9	9.6	12.2	18.8	13.8
18-19	23.5	24.6	23.	25.2	23.	26.7	23.5	27.5	23.5	24.1	21.2	26.9	41.6	30.5
1919-20	13.1	13.8	12.8	14.1	12.8	14.9	13.1	15.3	13.1	13.4	11.9	15.	23.2	17.

Season	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1902-3	25.5	26.7	37.9	25.5	29.4	40.3	31.1	20.5	37.7	26.6	21.7	30.9	23.3	37.3
3-4	24.9	26.1	37.1	24.9	28.8	39.4	30.4	20.	36.9	26.	21.2	30.2	22.8	36.4
4-5	30.1	31.6	44.8	30.1	34.8	47.6	36.7	24.2	44.5	31.5	25.6	36.5	27.5	44.
5-6	32.3	33.8	47.9	32.3	37.2	51.	39.3	25.9	47.7	33.7	27.4	39.1	29.4	47.
6-7	38.4	40.2	57.	38.4	44.2	60.6	46.8	30.8	56.7	40.	32.6	46.5	35.	56.
7-8	20.5	21.5	30.5	20.5	23.7	32.5	25.	16.5	30.4	21.4	17.5	24.9	18.7	30.
8-9	35.7	37.4	53.	35.7	41.1	56.4	43.5	28.6	52.7	37.2	30.3	43.2	32.5	52.1
9-10	23.8	24.9	35.4	23.8	27.5	37.6	29.	19.1	35.2	24.8	20.2	28.8	21.7	34.7
1910-11	36.	37.7	53.5	36.	41.6	56.9	43.9	28.9	53.3	37.6	30.6	43.7	32.9	52.6
11-12	17.3	18.3	25.7	17.3	20.	27.4	21.1	13.9	25.6	18.1	14.7	21.	15.8	25.3
12-13	13.2	13.9	19.6	13.2	15.3	20.9	16.1	10.6	19.5	13.8	11.2	16.	12.1	19.3
13-14	36.2	38.	53.8	36.2	41.8	57.3	44.2	29.1	53.6	37.8	30.8	43.9	33.1	52.9
14-15	33.3	34.9	49.5	33.3	38.5	52.7	40.6	26.8	49.3	34.8	28.4	40.4	30.4	48.7
15-16	27.5	28.8	40.8	27.5	31.7	43.4	33.5	22.	40.6	28.7	23.4	33.3	25.1	40.1
16-17	21.5	22.5	32.	21.5	24.8	34.	26.2	17.3	31.8	22.5	18.3	26.1	19.6	31.4
17-18	13.6	14.2	20.2	13.6	15.7	21.5	16.6	10.9	20.1	14.2	11.5	16.4	12.4	19.8
18-19	30.	31.4	44.5	30.	34.6	47.4	36.5	24.1	44.3	31.3	25.5	36.3	27.4	43.8
1919-20	16.8	17.5	24.9	16.8	19.3	26.5	20.4	13.4	24.8	17.5	14.2	20.3	15.3	24.4

RELATION OF LONG TO SHORT PERIOD AVERAGES

The relation of the mean rainfall at San Francisco to the mean of the means at the eight base stations is as follows:-

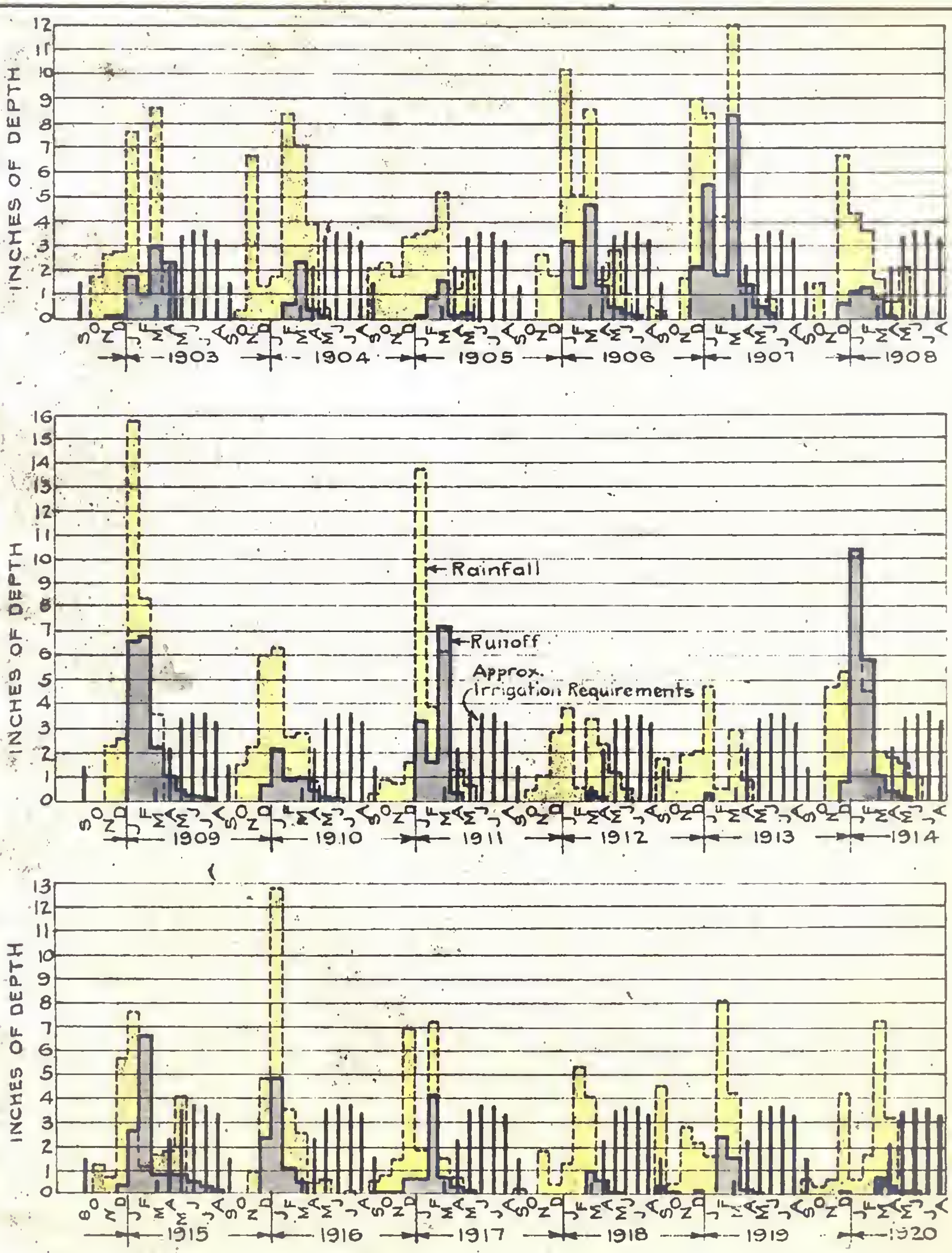
	71 yr. period	18 yr. period	Rate of Short to Long Period
San Francisco	22.48	20.58	91.5%
Eight Base Stations	23.05	21.68	94%

The 18 year period from 1902-1920 has been used as the rainfall period for detailed study for the reasons that it corresponds with the period of stream flow measurements on Coyote Creek, which drains the principal tributary watershed; its mean rainfall is slightly less than for the 71 year period, and it includes the two cycles of critically dry years of 1912-1913 and 1918-1920.

SEASONAL DISTRIBUTION

The seasonal distribution of rainfall is characteristic of that of California generally, coming principally between the months of October and April inclusive.

On plate 9 is shown graphically the monthly rainfall over the Coyote watershed, obtained by comparing its mean annual with the mean annual and monthly rainfall at Mt. Hamilton. The Coyote has been selected as typical.



SANTA CLARA VALLEY

WATER CONSERVATION PROJECT

MONTHLY DISTRIBUTION OF COYOTE RAINFALL AND RUN-OFF

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March 1921

RUNOFF

GENERAL

Having determined the areas of the various component watersheds, and the normal and mean annual rainfall over the same, the next step in determining the available water supply for this project is that of computing the probable water runoff.

Available statistics of stream flow are limited and not well distributed.

The Bay Cities Water Company measured the stream flow of Coyote Creek with very great detail and accuracy from 1902 to 1909 and with less detail from 1909 to 1914. For the years 1917 to date the stream has been gaged by the U.S.G.S. Uvas Creek was gaged by the Bay Cities Water Company in the years 1903 to 1907, and Llagas Creek in the years 1903 to 1906. From water consumption records, wasteway discharge measurements and reservoir evaporation, the runoff of San Francisquito Creek, above Searsville Lake, has been computed (Herrmann) for the years 1893 to 1918. The discharge of Calaveras Creek from 1889 to 1912 has been gaged by the Spring Valley Water Company. From these gagings we have actual records of stream flow on five streams; three in the South Central portion, and one each at the extreme North end of the Western and Eastern arms of the watershed area. The Calaveras does not drain into any portion of the Santa Clara Valley, but its proximity on the East makes its record of comparative value.

It is fortunate that the record is so complete on the Coyote, since this drains the entire Southeastern portion and about one-third of the total watershed area. By comparison of the records in years of common observation it has been possible to study the performance relation

between the Coyote, Uvas and Llagas Creeks, and thus form opinions and draw conclusions as to the probable reasonable performance of the entire Southern portion of the watershed between the points of maximum rainfall around Loma Prieta and the summit of the Santa Cruz range on the West, and Mt. Hamilton on the East. Deductions thus made possible for the Southwestern portion of the watershed have been extended, by a logical and reasonable consideration of the influence of topographic and other features, along the Western arm of the watershed to join in with the performance record of San Francisquito Creek. On the East similar reasoning has extended the performance record of Coyote Creek Northward toward Calaveras.

CHARACTERISTICS OF WATERSHEDS

The Eastern watershed South to the Coyote (Fig. 8) rises abruptly from the valley floor. The hills next the valley are steep, mostly grass covered, and cut with small but deep and sharply defined canons and water courses. The more protected canon slopes are heavily brush covered, and on the higher levels there is a scattering growth of timber. There is a quite uniformly distributed soil cover of good depth, particularly in the farming region known as Halls Valley, and on the broad hill tops and less abrupt slopes of the Eastern half of the area and in the South along Dry and Silver Creeks.

The Coyote drainage area (Fig. 5) is similar in its general characteristics to those of the area just described, but generally more rugged and inaccessible. There are fewer and smaller valley areas, the soil cover is somewhat lighter, and the brush and timber cover generally heavier.

View of Eastern Watershed from Coyote Creek-Upper Gorge Dam Site.

FIG. 5.

Characteristic view Santa Cruz Mountain Watersheds from Stevens Creek Upper Dam Site.

FIG. 6.

Watershed between Almaden and Llagas Creeks, from Calero Creek Dam Site.

FIG. 7.

Narrows of the Coyote Creek.

FIG. 8.

The general character of the watershed draining the slopes of the Coast Range in the West differs materially from that on the East. Here, except for a narrow margin of rolling soil covered foothills adjoining the main valley floor, the slopes rise steeply and uniformly to the crest of the Coast Range. The streams in their sharp descent to the valley have cut deep and precipitous canons. From the Uvas North to Stevens Creek the watersheds of all the streams are heavily brush and timber covered, (Fig. 6.) spruce and redwood timber largely predominating on the higher levels. Uvas, Los Gatos, Campbell, Stevens and San Francisquito Creeks have their origin at the summit and drain the entire tributary length of the Coast Range. The same conditions influencing the runoff from the Uvas Creek watershed prevail on the other primary drainages of Los Gatos, Campbell and Stevens Creeks. Llagas Creek watershed is typical of those of Alamitos (Fig. 7) and Guadalupe Creeks, which may be classed as secondary in the Western group, with slightly less average elevation, scantier cover and proportionately more of the lower foothill slopes. North of the Stevens Creek drainage xx the San Francisquito watershed and the smaller watersheds toward the East and North rapidly take on the characteristics of the more open deeply soil covered slopes of the lower rolling foothills, with extensive cultivated areas. Taking into account these features of similarity, or of graduated variation, in the topographic and other characteristics of the various portions of the general watershed, a probable runoff value for each portion has been assigned.

METHOD OF ESTIMATING RUNOFF

Careful consideration has been given to those methods of computing the runoff from a watershed as advanced by students, and set forth in the literature, of the subject.

Wherever actual stream gaugings are available direct results are obtained without futher knowledge of the factors entering the problem. Such direct information, however, is rarely available, and is particularly lacking in this study, where the total available water supply is contributed by numerous independent tributary streams. The most commonly used method of calculating the probable runoff from a watershed is that of the runoff curve. By taking the mean seasonal rainfall over one or a number of watersheds, and the gaged stream flow from the same, points may be plotted on co-ordinate paper to show the relation of any given runoff to its corresponding rainfall. Throgh the points thus plotted a mean curve may be drawn to represent inches of runoff in terms of inches of rainfall. Due to dissimilarity in seasonal storm conditions this curve represents runoff probabilities during a long time period, and the actual runoff may vary seasonally, over a wide margin. But the long time average will equalize the effect of local variations, particularly if the curves are drawn from local observations of and for specific watersheds, as in this case.

The runoff from streams, based entirely upon the theory of probabilities, and without reference to known or estimated rainfall over the watershed for any given year, has had close study by several writers.

This subject was discussed by Mr. Allen Hazen, M. Am. So. C.E., in a paper published in the transactions of the American Society of Civil Engineers, Vol. 77 (1914), and further studied with reference to California streams and discussed in a paper before the American Society of Civil Engineers, by Mr. L. Standish Hall, Jun. Am. So. C.E. Mr. Hall has proposed what he terms an "Hydraulic Probability Paper", which "can be used in estimating the relative wetness and dryness of individual years, in terms of the probable absolute wettest and dryest years. By using these indices (taken from Probability Paper) of the relative wetness and dryness, the probable values of the yearly runoff can be estimated for streams for which there are few or no runoff records, and for as many years as runoff measurements have been taken on neighboring drainage areas."

Another method carefully analysed and discussed is presented by Mr. Adolf F. Meyer, M. Am. So. C.E., in a paper entitled "Computing Runoff from Rainfall and other Physical Data", and published in Trans. Am. Soc. Civil Eng. Vol. 79 (1915). This method has for its basis determination of rainfall over the watershed, from which (based upon personal judgment as to physical characteristics and the application of certain arbitrary co-efficients) must be deducted losses due to absorption, evaporation and plant transpiration. After deducting losses due to these factors the residue is the runoff. This involves very thorough knowledge and study of topography, soil cover, rock formation, temperature and wind movement.

Because of the theoretical assumptions involved in the last two methods, which could only result in theoretical deductions based upon fundamental data that at best is limited and weighted judgment upon numerous essential factors upon which information is very inadequate, it has been concluded that the method of the runoff curve will give the most satisfactory results for this study.

In determining the runoff curves to be used the curves prepared by Mr. Edwin Duryea, Jr., M. Am. Soc. C.E., based upon his study of the Coyote, Uvas and Llagas Creek watersheds, have been adopted. These curves were prepared from the plotting of rainfall records for 133 rain gage stations over these watersheds, and the careful gaging of the streams for a number of years. The stream flow of the Coyote has been gaged every year except 1915 and 1916, since 1902, and the Uvas and Llagas for four and three year periods respectively. The curves plotted by Mr. Duryea are designated as (a), (b), (c), and (d). Modifications of the curves (as means) have been used where judgment dictated to suit local conditions. These curves are shown on Plate 10. Diagram #1 gives the runoff in inches of rainfall, and Diagram #2 the same thing in percent of rainfall, with the equation for the same.

Wherever actual stream gagings are available these have been used, and other years filled in from the curves. The results thus obtained on the Uvas and Llagas have been used as the basis,

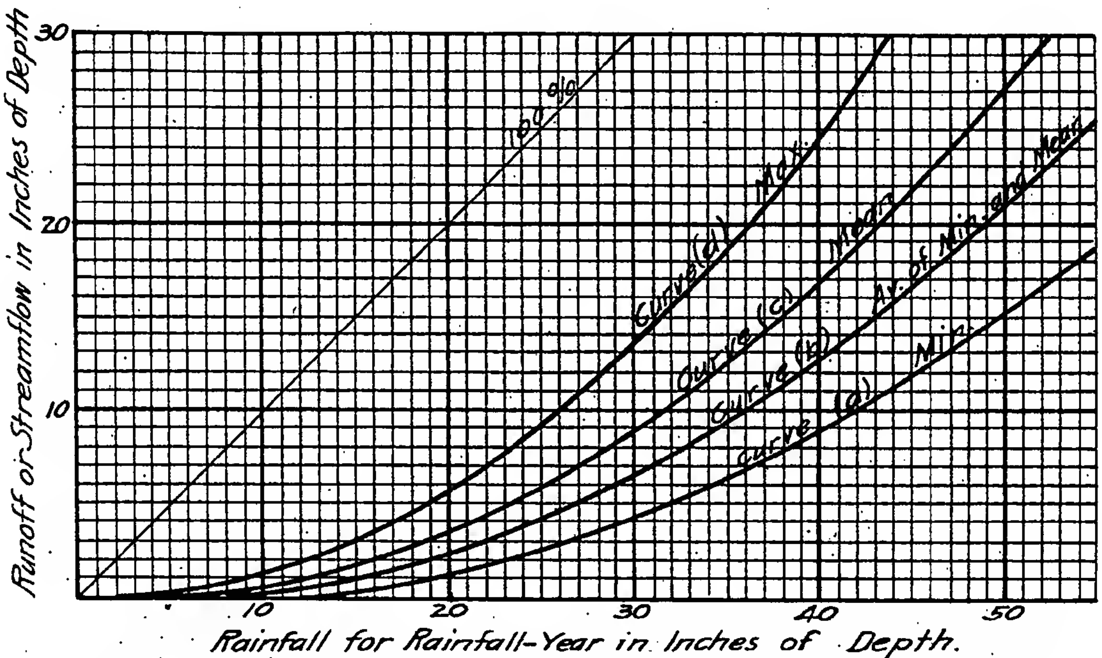


Diagram 1 - Streamflow and Rainfall in Inches of Depth

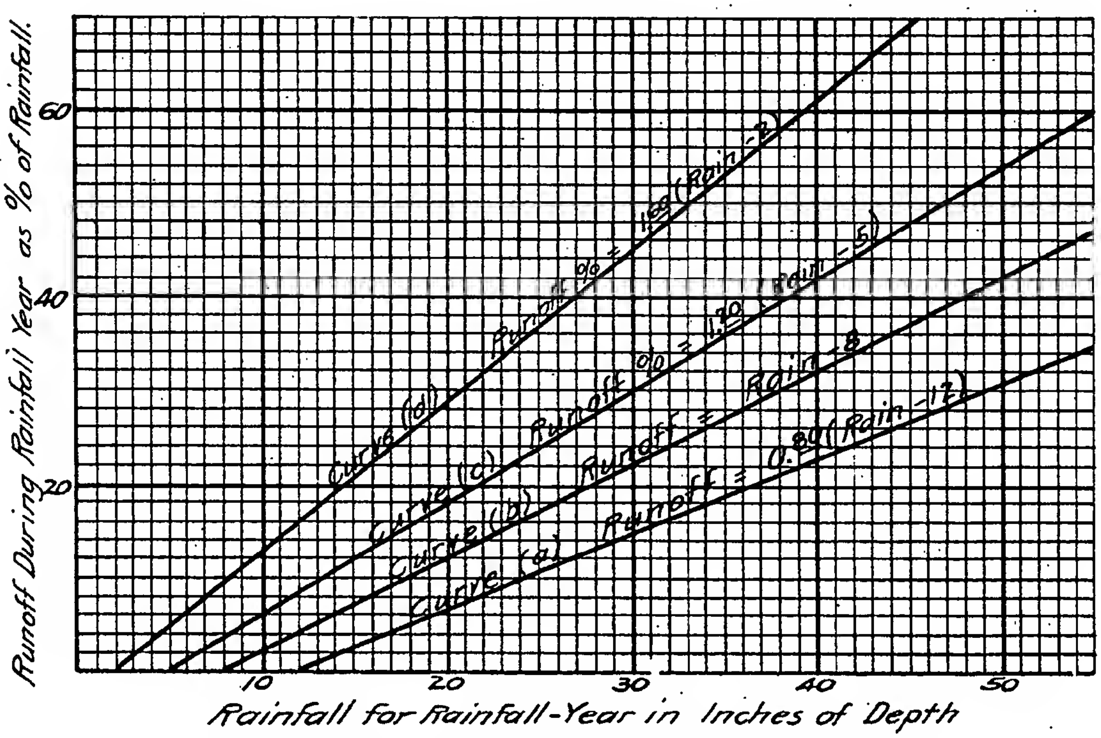


Diagram 2 - Rainfall in Inches of Depth - Streamflow as % of Rainfall.

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

RUN-OFF CURVES

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

March 1921

PLATE 10

by direct proportioning of the rainfall, for those watersheds for which they are considered as representative, namely; the Uvas for Los Gatos, Campbell and Stevens Creeks and the Llagas for Upper Alamitos, Guadalupe and Penitentia Creeks. San Francisquito and Upper Los Trancos Creeks have been given the Hermann rating, determined from gagings at Searsville Lake, which corresponds very closely with curve (a). All other watersheds have been assigned curves varying from (c) down to (a), dependent upon location and seasonal rainfall conditions. Different curves on the same watersheds are selected for different years dependent upon the characteristic delivery of the rainfall for that year. In this manner it is believed that the best possible advantage has been taken of the extensive local knowledge of actual conditions on a few of the principal portions of this area to arrive at a graduated and carefully weighted estimate of the runoff from the entire watershed.

ESTIMATED RUNOFF.

Based on the foregoing method of using actual stream gagings wheree available, supplemented by runoff curves, the runoff from the various tributary watersheds has been computed for each year from 1902 to 1920. This period has been selected for the reasons stated under the discussion of rainfall, and it is believed to represent a period covering years of both maximum and normal runoff, and rather more than a normal proportion of years of drouth. That this period

may be contrasted with the longer 71 year period extending back to 1849 the estimated runoff for the Coyote has been computed for that period, and the mass diagram of this runoff plotted. From this diagram (see Plate 65) it will be observed that years of exceptional drouth occurred in the following years; 1920, 1918, 1912, 1913, 1877, 1871, 1864 and 1863. Of these years of very low runoff four out of the eight have occurred during the last eighteen years. Similar cummulative effects of cycles of dry years have occurred in 1918-1920, 1912-1913, 1904-1905, 1899-1900, 1891-1892, 1888-1889, 1882-1883, 1870-1871, 1863-1864.

In using the last eighteen year period, therefore, for determining the average runoff from these watersheds, as the basis for study of conservation of water, it is believed maximum conditions have been covered, and that these conditions are fairly representative of the long time normal.

TABLE 10.

ESTIMATED SEASONAL RUNOFF FROM BASE (REFERENCE) WATERSHEDS

SEASON	Coyote (12)+ Rainfall Inches	Coyote Runoff Ac. Ft.	Coyote Runoff %	Uvas (13)+ Rainfall Inches	Uvas Runoff Ac. Ft.	Uvas Runoff %	Llagas (14)+ Rainfall Inches	Llagas Runoff Ac. Ft.	Llagas Runoff %	San Francisquito (28)+ Rainfall Inches	San Francisquito Runoff Ac.Ft.	San Francisquito Runoff %
1902-3	23.6	(1) 83000	34.1	33.5	(3) 22600	42.3	24.6	(3) 7750	30.6	37.3	(6) 12280	21.4
3-4	20.4	(1) 26500	16.9	36.8	(1) 27860	47.7	27.	(1) 9320	32.8	36.4	15060	26.9
4-5	26.6	(1) 32000	11.6	41.3	(1) 21050	32.1	30.4	(1) 7550	23.7	44	10200	15.2
1905-6	30.8	(1) 116400	36.7	47.	(1) 42220	57.	34.5	(1) 16610	46.	47.1	24600	34
6-7	36.4	(1) 202000	54.3	50.8	(1) 42890	53.3	37.3	(3) 18640	47.7	56.	32700	38
7-8	19.	(1) 47200	24.	28.2	(2) 12370	27.8	20.7	(2) 4080	19	30.	9920	21.6
8-9	31.3	(1) 176000	54.7	51.	(3) 54090	67.	37.4	(3) 18750	47.8	52.1	31530	39.4
1909-10	21.8	(1) 51500	22.8	33.6	(3) 22530	42.5	24.7	(3) 7750	30.	34.7	10490	19.6
10-11	30.9	(1) 126300	39.8	45.6	(3) 42830	59.3	33.5	(3) 14870	42.3	52.6	31400	38.8
11-12	16.1	(1) 6390	3.85	24.4	(2) 9040	23.3	17.9	(2) 2930	15.5	25.3	8200	33.2
12-13	12.6	(1) 3845	2.97	19.1	(5) 3330	11.1	14.	(5) 900	6.	19.3	1010	3.6
13-14	33.9	(1) 189000	54.2	59.5	(2) 62100	65.3	43.6	(2) 21160	46.3	52.9	26710	32.9
1914-15	29.9	(4) 138000	44.6	46.3	(3) 44100	60.5	33.9	(3) 15110	42.8	46.7	20600	27.5
15-16	24.6	(4) 92000	36.2	38.1	(3) 29359	48.6	27.9	(3) 9990	34.5	40.1	29790	46.4
16-17	19.3	(1) 69900	34.4	29.9	(3) 17770	37.4	21.9	(3) 5970	26.1	31.4	10930	22.6
17-18	12.2	(1) 12270	9.8	18.8	(2) 4960	16.6	13.8	(2) 1540	10.5	19.8	2540	8.6
18-19	26.9	(1) 50440	16.7	41.6	(2) 29100	44.	30.5	(2) 9400	30.6	43.8	17200	25.5
1919-20	15.0	(1) 14130	9.1	23.2	5550	15.2	17.0	1570	9.	24.4	3685	10.
Mean	24.8	80380	24.3	38.	27440	45.5	27.8	9660	32.2	36.7	16600	29.6

(1) Gaged
(2) Curve (c)
(3) Mean of curves (c) and (d)
(4) Curve (d)
(5) Curve (b)
(6) Herrmann rating for Searsville Lake
\+ Runoff for Coyote, Uvas and Llagas only for that portion of watersheds above reservoirs. San Francisquito runoff for that portion of watershed above proposed Stanford Dam #3 just above junction with Los Trancos.

The foregoing table for the main reference watersheds serves to show the seasonal variation of runoff. Similar computations and tables, based on the 18 year mean rainfall given in Table 7, have been prepared for each of the other watersheds. For greater detail such studies have also been made on additional sub-divisions of certain of the watersheds, where there were great variations in rainfall and runoff conditions, namely; Alamitos, Guadalupe, Stevens, Permanente, San Antonio, Madera and San Francisquito-Los Trancos Creeks. Plates 11 to 22, inclusive, show graphically the seasonal and cummulative runoff for the principal valley streams for the 18 year period. The following Table 11 shows a general summary of the average runoff for all of the watersheds, including the basic data for the same. Further detail as to maximum, minimum and average runoff is given in Table 15.

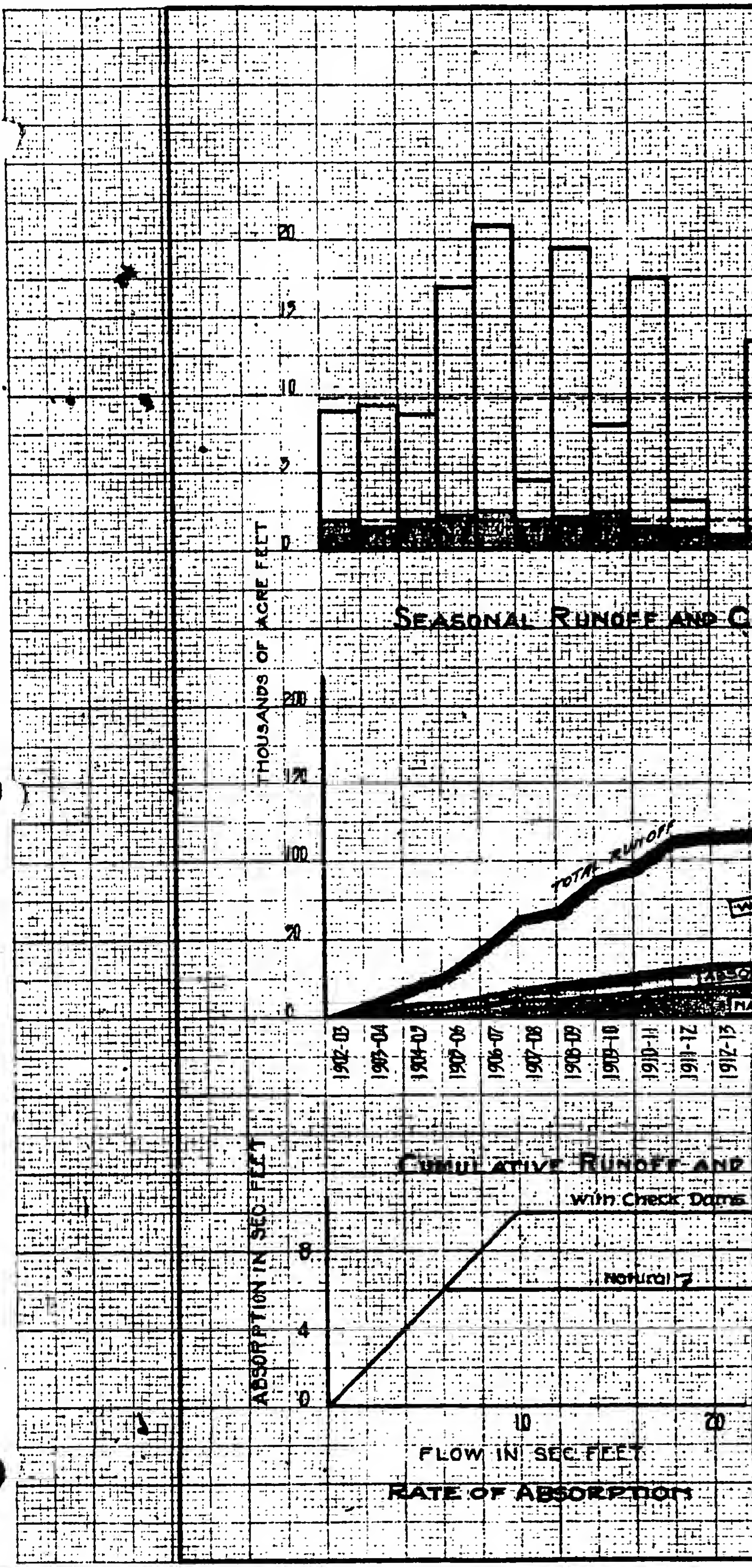
TABLE 11.
SUMMARY OF AVERAGE RUNOFF FROM ALL WATERSHEDS FOR 18 YEAR PERIOD

No.	Watershed Name	Rain Inches	Runoff Curve Used	Av. Seasonal Runoff Ac. Ft.
1	Scott	21.5	b	155
2	Calera	22.5	c	625
3		21.	b	175
4	Los Coches	23.	c	960
5		21.	b	140
6	Berryessa	24.4	c	1450
7		21.5	b	290
8	Penitencia	25.1	Llagas	9920
9		21.5	b	310
10		22.	b	870
11	Evergreen	19.4	b	3470
12	Coyote	24.82		80380
12 a,d	"	18.	b	2045
12b	"	17.2	b	520
12c	"	17.5	b	335
13	Uvas	38.		27440
14	Llagas			
	Upper	27.8		9660
	Lower	23.5		1370
			Forward	140115

TABLE 11. - Con.
SUMMARY OF AVERAGE RUNOFF FROM ALL WATERSHEDS FOR
18 YEAR PERIOD

No.	Watershed Name	Rain Inches	Runoff Curve Used	Av. Seasonal Runoff Ac. Ft.
			Br. Forward	140115
14a		21.	b	1930
14b		25.	b	1480
14c		20.	b	550
15	Alamitos			
	Upper	35.6	Llagas	6360
	Lower	23.4	c	4395
	Calero	24.1	c	2205
16	Guadalupe			
	Upper	32.8	Llagas	3240
	Lower	25.8	Llagas	3570
17	Los Gatos	40.7	Uvas	42330
18		27.4	b	950
19	San Tomas	31.6	b	2100
20	Campbell	43.3	Uvas	11880
21	Calabazas	33.4	b	1650
22		22.	b	155
23	Stevens			
	Upper	42.4	Uvas	17580
	Lower	26.6	b	1530
24	Permanente			
	S. Fork	33.5	b	1560
	N. Fork	28.6	b	1075
	Lower	23.3	a	150
25		23.3	a	315
26	San Antonio			
	Upper	33.2	b	1305
	Lower	24.2	a	440
27	Madera			
	Upper-N. Fork	25.	a	510
	Lower-S. Fork	21.8	a	575
28	San Francisquito			
	Upper	40.	Herrmann	16600
	Lower	24.2	a	785
	Upper Los Trancos	32.8	Herrmann	2570
				267905

A compilation from the foregoing tabulation of the runoff from the various watersheds shows the following regional distribution.

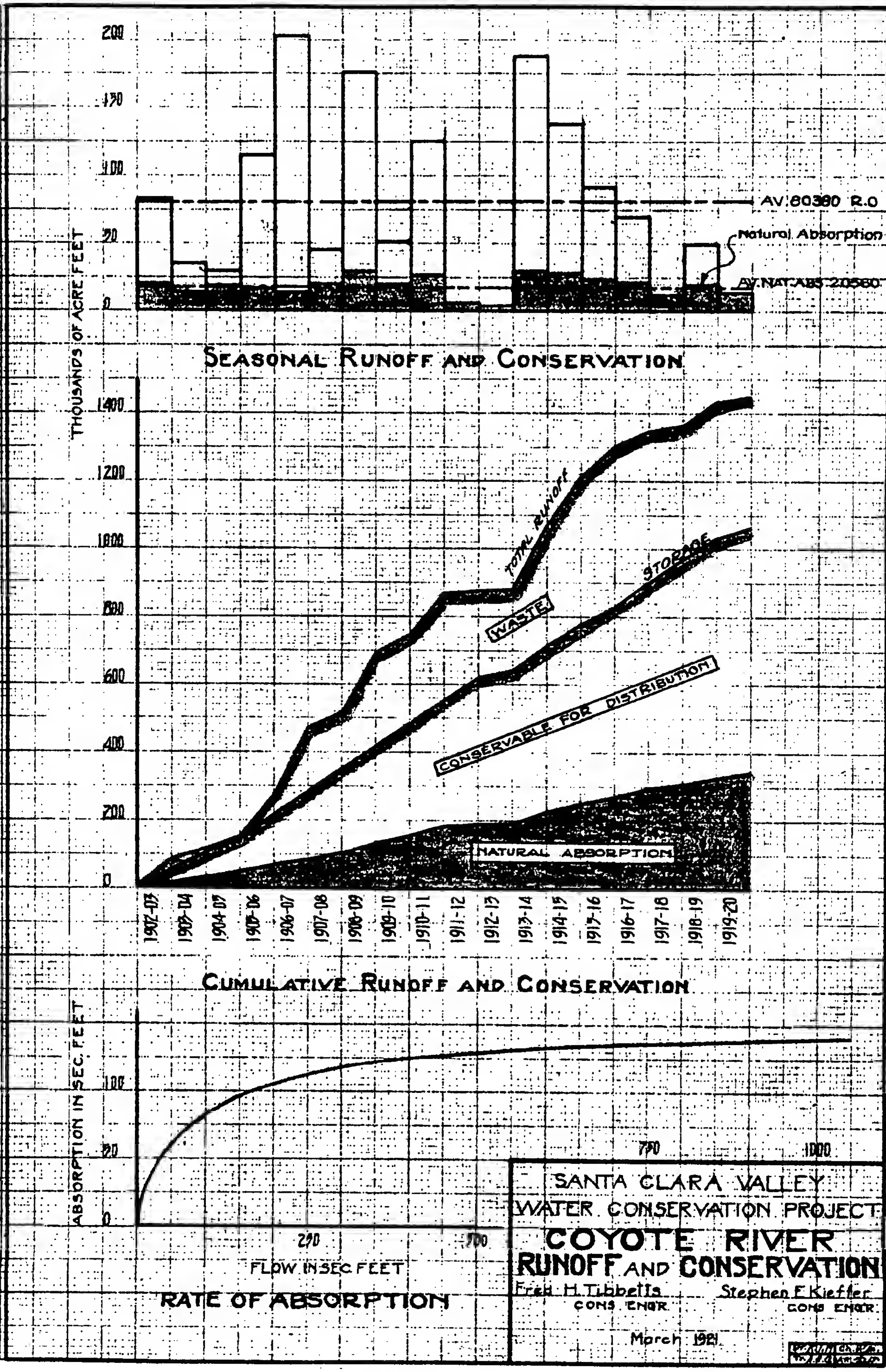


SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
PENITENCIA CREEK
RUNOFF AND CONSERVATION

Fred. H. Tibbetts, Cons. Engr. — Stephen E. Kieffer, Cons. Engr.

March 1921

PLATE 11



THOUSANDS OF ACRE FEET
200
150
100
50
0
AV. 80380 R.O
Natural Absorption
AV. NAT. ABS. 20560
SEASONAL RUNOFF AND CONSERVATION
1400
1200
1000
800
600
400
200
0
TOTAL RUNOFF
WASTE
STORAGE
CONSERVABLE FOR DISTRIBUTION
NATURAL ABSORPTION
1902-03
1903-04
1904-05
1905-06
1906-07
1907-08
1908-09
1909-10
1910-11
1911-12
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
CUMULATIVE RUNOFF AND CONSERVATION
ABSORPTION IN SEC. FEET
100
50
0
250
500
750
1000
FLOW IN SEC FEET
RATE OF ABSORPTION
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
COYOTE RIVER
RUNOFF AND CONSERVATION
Fred H. Tibbetts
CONS. ENGR.
Stephen E. Kieffer
CONS. ENGR.
March 1921

PLATE 12

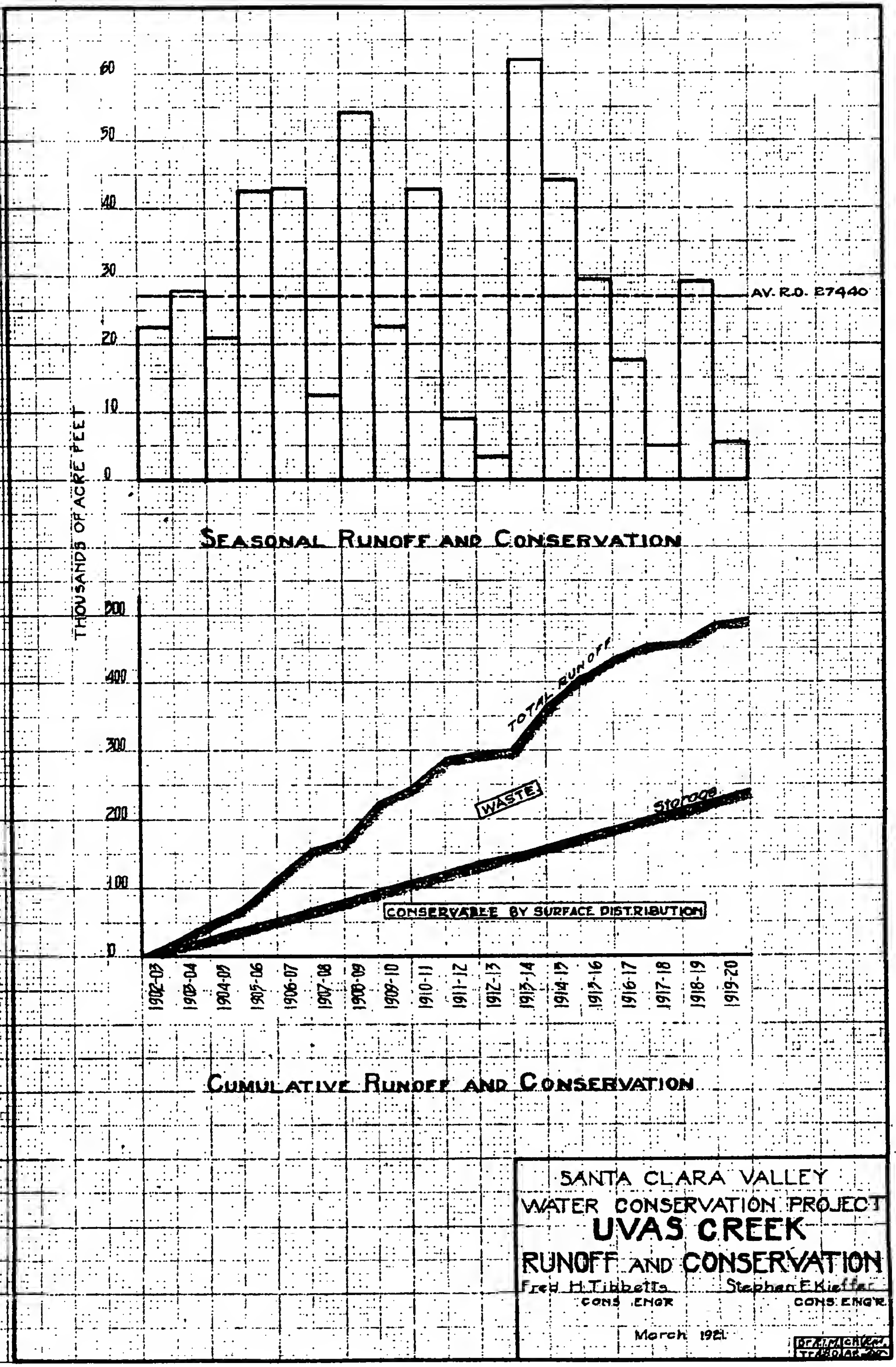
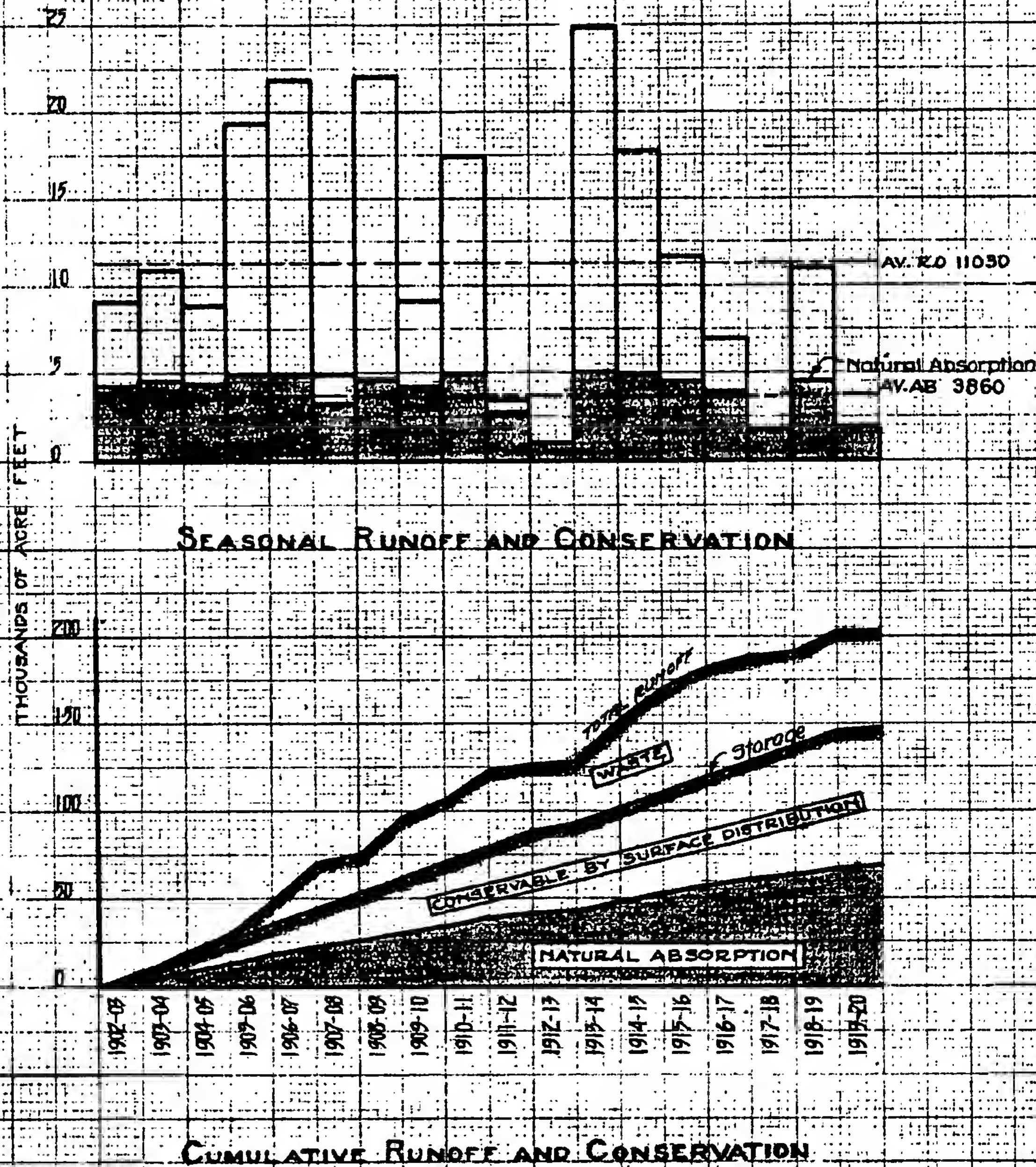

THOUSANDS OF ACRE FEET
60
50
40
30
20
10
0
AV. R.O. 27440
SEASONAL RUNOFF AND CONSERVATION
500
400
300
200
100
0
TOTAL RUNOFF
WASTE
Storage
CONSERVABLE BY SURFACE DISTRIBUTION
1902-03
1903-04
1904-05
1905-06
1906-07
1907-08
1908-09
1909-10
1910-11
1911-12
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
CUMULATIVE RUNOFF AND CONSERVATION
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
UVAS CREEK
RUNOFF AND CONSERVATION
Fred H. Tibbetts
CONS. ENGR.
Stephen E. Kieffer
CONS. ENG'R.
March 1921

PLATE 13

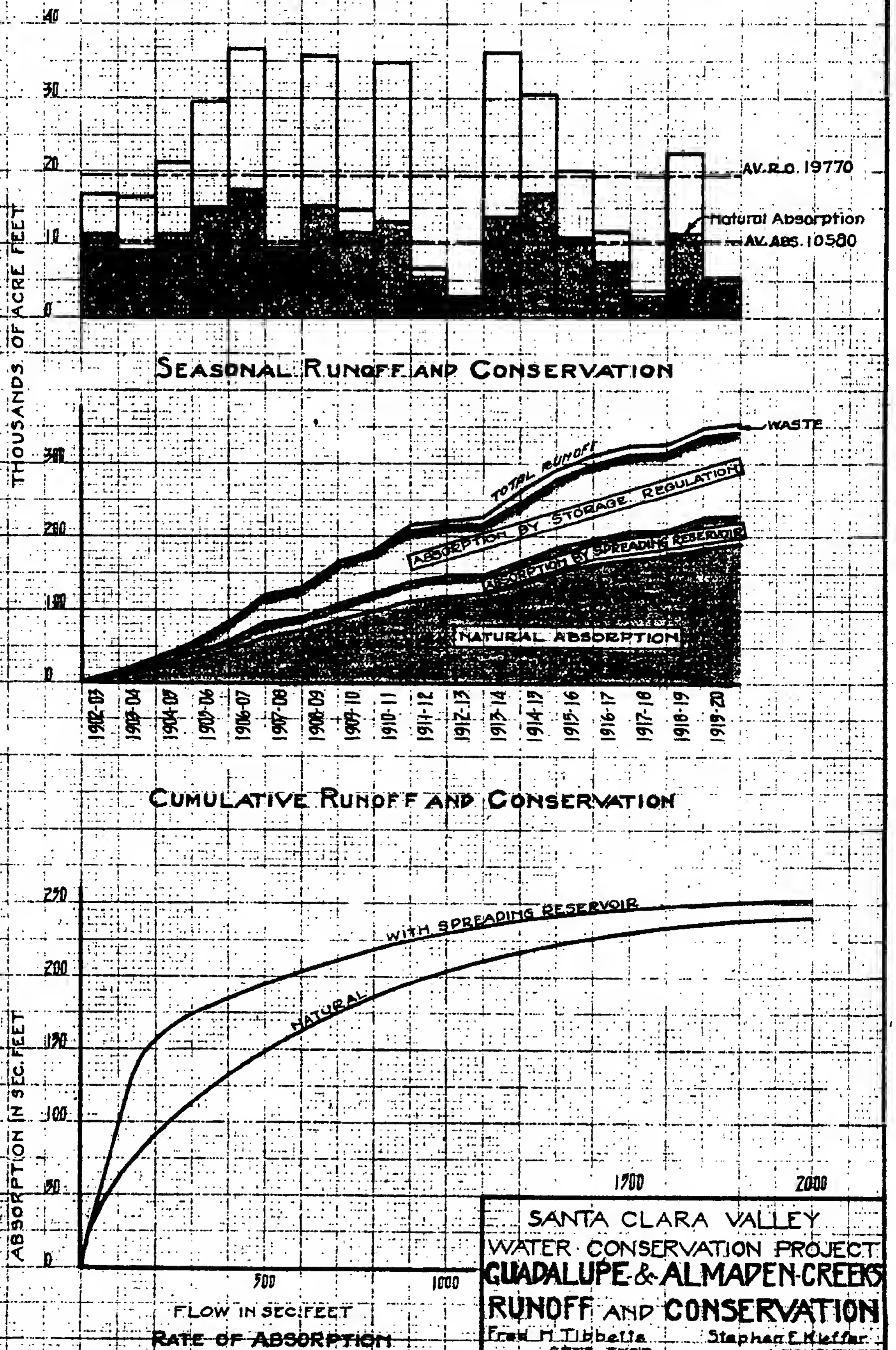


SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
LLAGAS CREEK
RUNOFF AND CONSERVATION

Fred H. Tibbetts, Cons. Engr. — Stephen E. Kieffer, Cons. Engr.

March 1921

PLATE 14



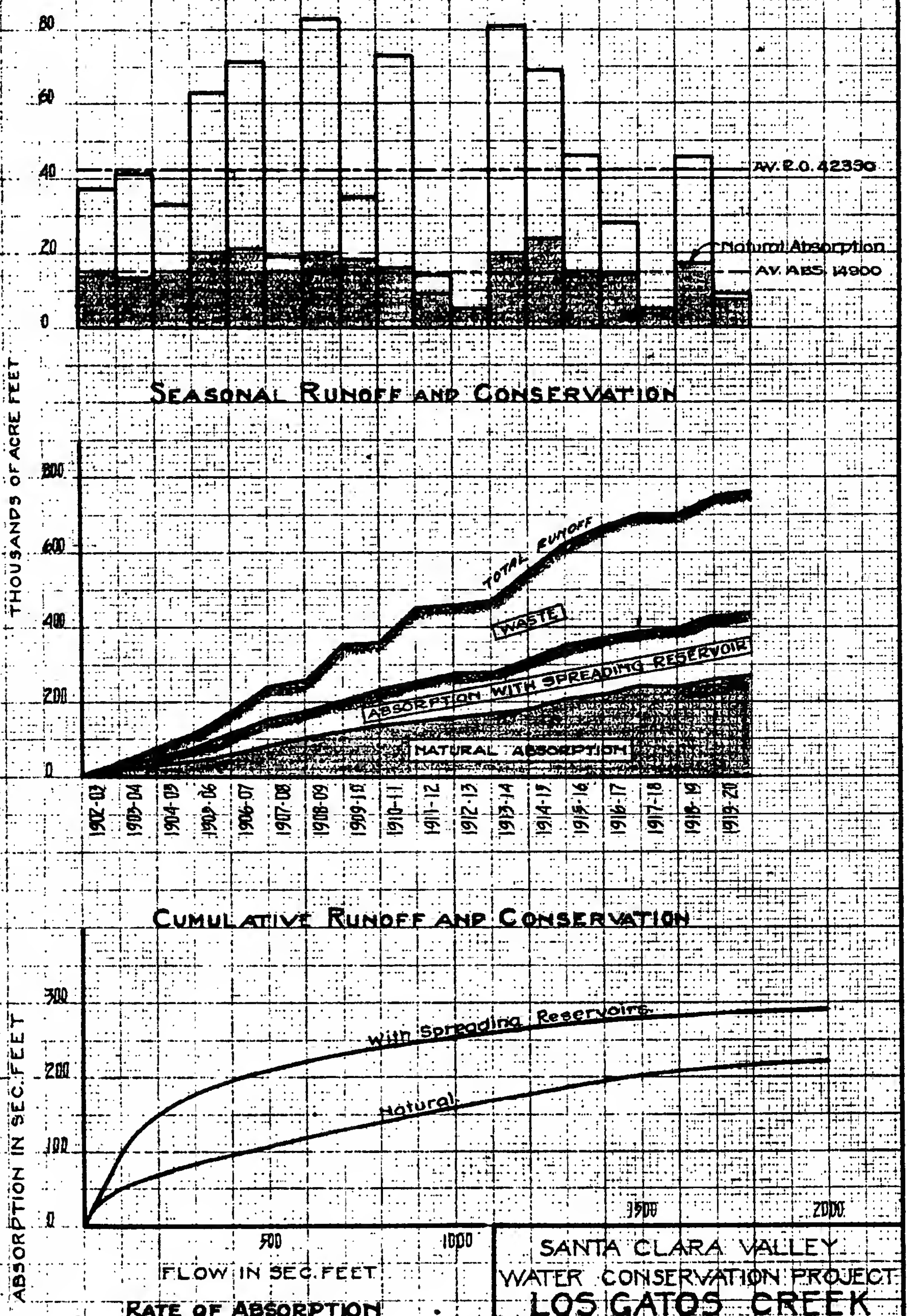
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
GUADALUPE & ALMADEN CREEKS
RUNOFF AND CONSERVATION

Fred H Tibbetts
CONS. ENG'R

Stephen E Kieffer
CONS. ENG'R

March 1921

PLATE 15



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
LOS GATOS CREEK
RUNOFF AND CONSERVATION

Fred H Tibbetts, CONS. ENGR. — Stephen E. Kieffer, CONS. ENG'R.

March 1921

PLATE 16

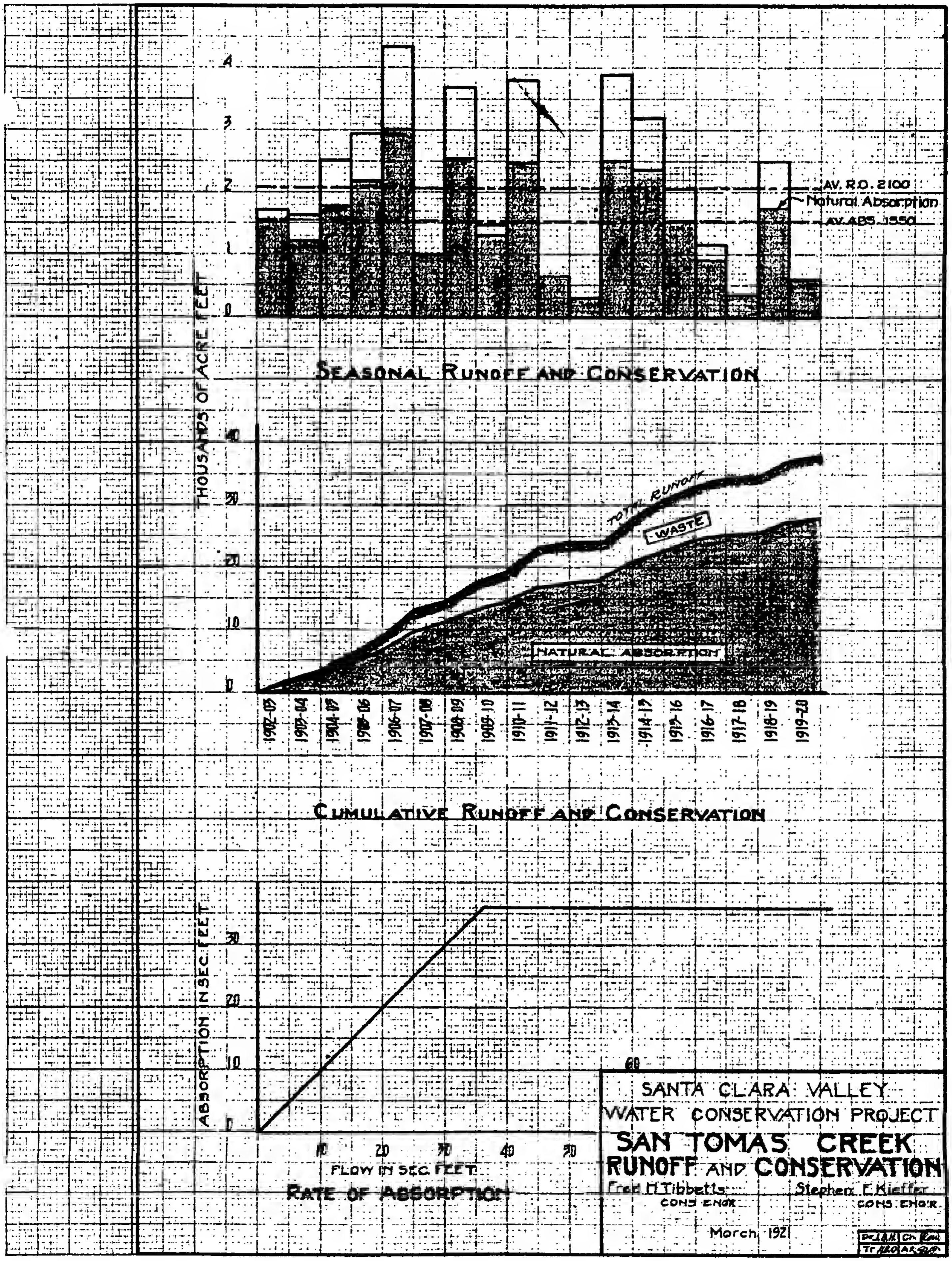
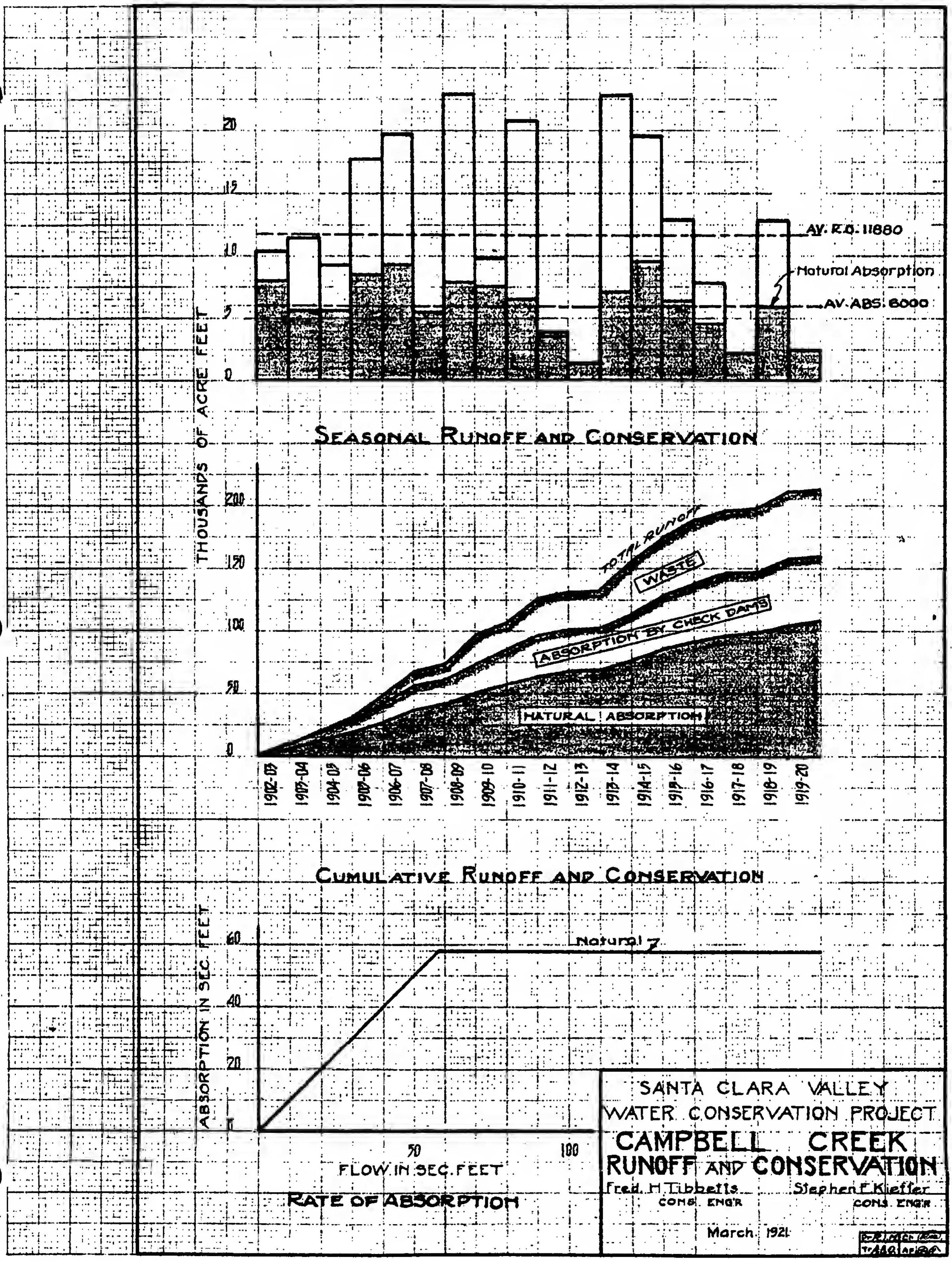
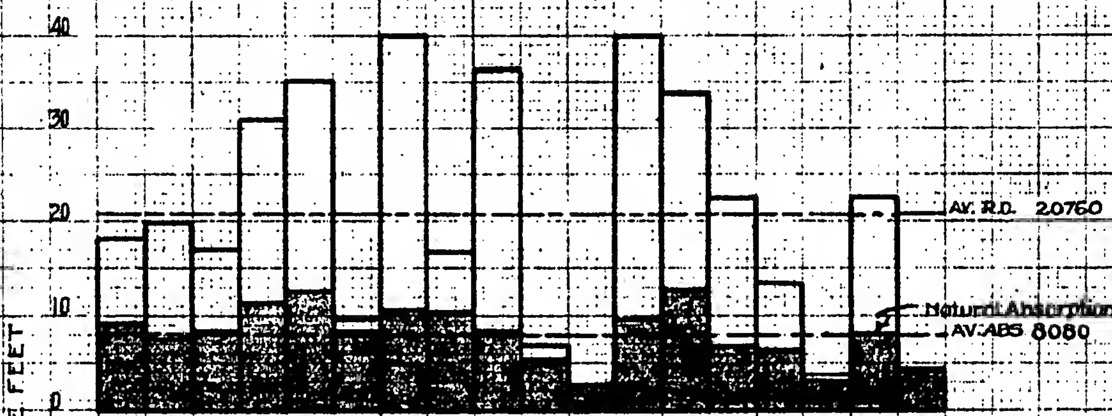

AV. R.O. 2100
Natural Absorption
AV. ABS. 1550
THOUSANDS OF ACRE FEET
SEASONAL RUNOFF AND CONSERVATION
TOTAL RUNOFF
WASTE
NATURAL ABSORPTION
1902-03
1903-04
1904-05
1905-06
1906-07
1907-08
1908-09
1909-10
1910-11
1911-12
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
CUMULATIVE RUNOFF AND CONSERVATION
ABSORPTION IN SEC. FEET
FLOW IN SEC. FEET
RATE OF ABSORPTION
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
SAN TOMAS CREEK
RUNOFF AND CONSERVATION
Fred H Tibbetts
CONS. ENGR.
Stephen E Kieffer
CONS. ENG'R.
March 1921

PLATE 17

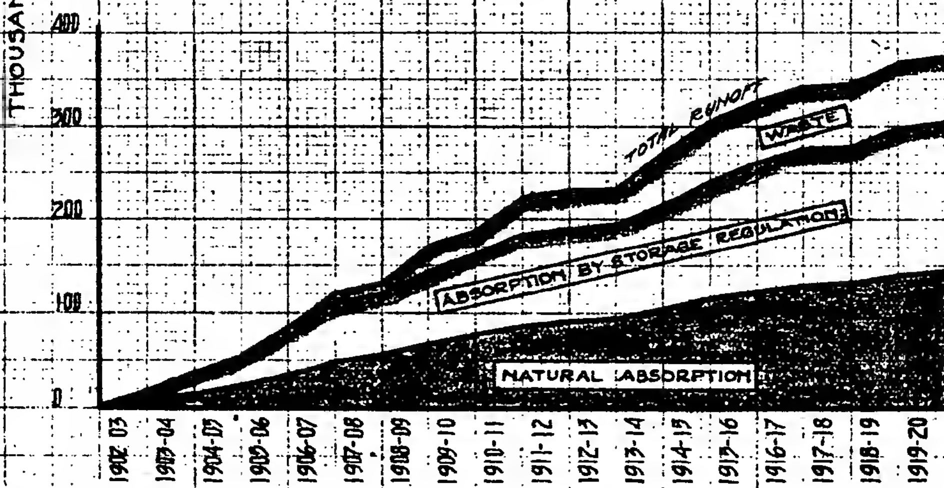


THOUSANDS OF ACRE FEET
20
15
10
5
0
AV. R.O. 11880
Natural Absorption
AV. ABS. 6000
SEASONAL RUNOFF AND CONSERVATION
200
150
100
50
0
TOTAL RUNOFF
WASTE
ABSORPTION BY CHECK DAMS
NATURAL ABSORPTION
1902-03
1903-04
1904-05
1905-06
1906-07
1907-08
1908-09
1909-10
1910-11
1911-12
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
CUMULATIVE RUNOFF AND CONSERVATION
ABSORPTION IN SEC. FEET
60
40
20
0
Natural
50
100
FLOW IN SEC. FEET
RATE OF ABSORPTION
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
CAMPBELL CREEK
RUNOFF AND CONSERVATION
Fred. H. Tibbetts
CONS. ENG'R
Stephen E. Kieffer
CONS. ENG'R
March 1921

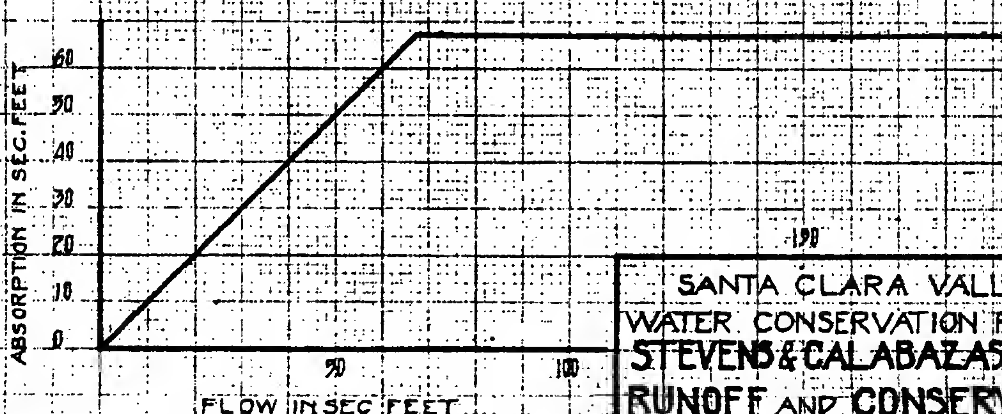
PLATE 18



SEASONAL RUNOFF AND CONSERVATION



CUMULATIVE RUNOFF AND CONSERVATION



RATE OF ABSORPTION

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
STEVENS & CALABAZAS CREEKS
RUNOFF AND CONSERVATION

Fred. H. Tibbetts, CONS. ENGR. — Stephen E. Kieffer, CONS. ENGR.

March 1921

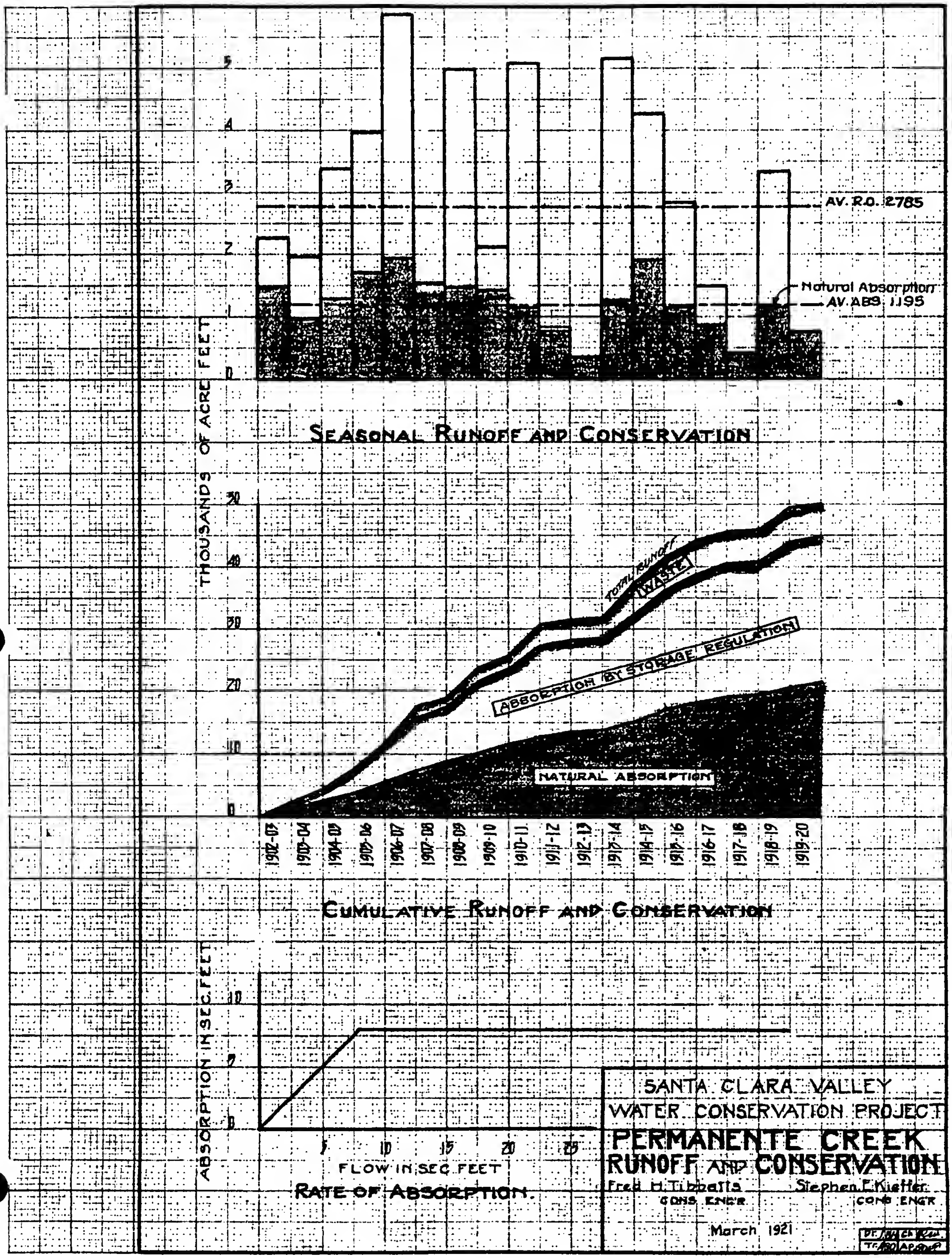
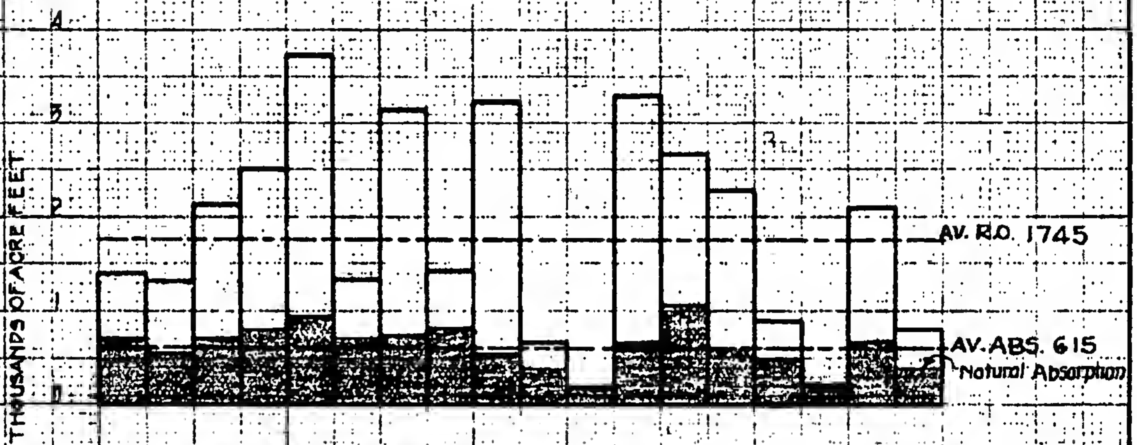
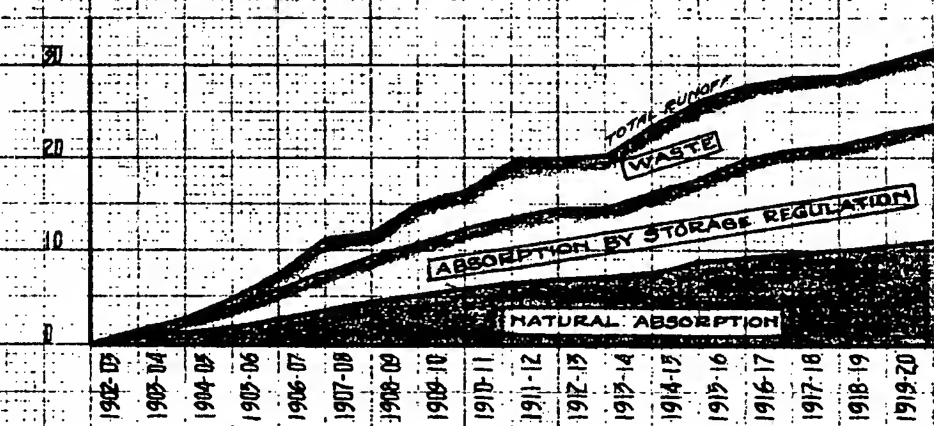

AV. R.O. 2785
Natural Absorption
AV. ABS. 1195
THOUSANDS OF ACRE FEET
SEASONAL RUNOFF AND CONSERVATION
TOTAL RUNOFF
WASTE
ABSORPTION BY STORAGE REGULATION
NATURAL ABSORPTION
1902-03
1903-04
1904-05
1905-06
1906-07
1907-08
1908-09
1909-10
1910-11
1911-12
1912-13
1913-14
1914-15
1915-16
1916-17
1917-18
1918-19
1919-20
CUMULATIVE RUNOFF AND CONSERVATION
ABSORPTION IN SEC. FEET
FLOW IN SEC FEET
RATE OF ABSORPTION.
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
PERMANENTE CREEK
RUNOFF AND CONSERVATION
Fred H. Tibbetts
CONS. ENG'R
Stephen E. Kieffer
CONS. ENG'R
March 1921

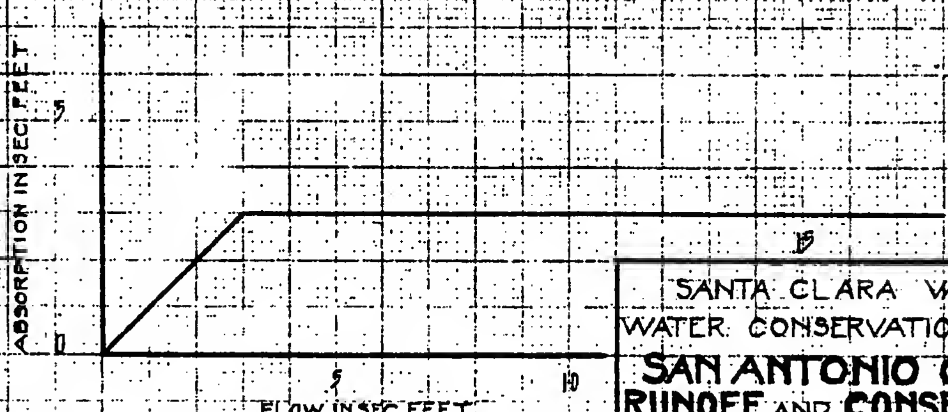
PLATE 20



SEASONAL RUNOFF AND CONSERVATION



CUMULATIVE RUNOFF AND CONSERVATION



RATE OF ABSORPTION.

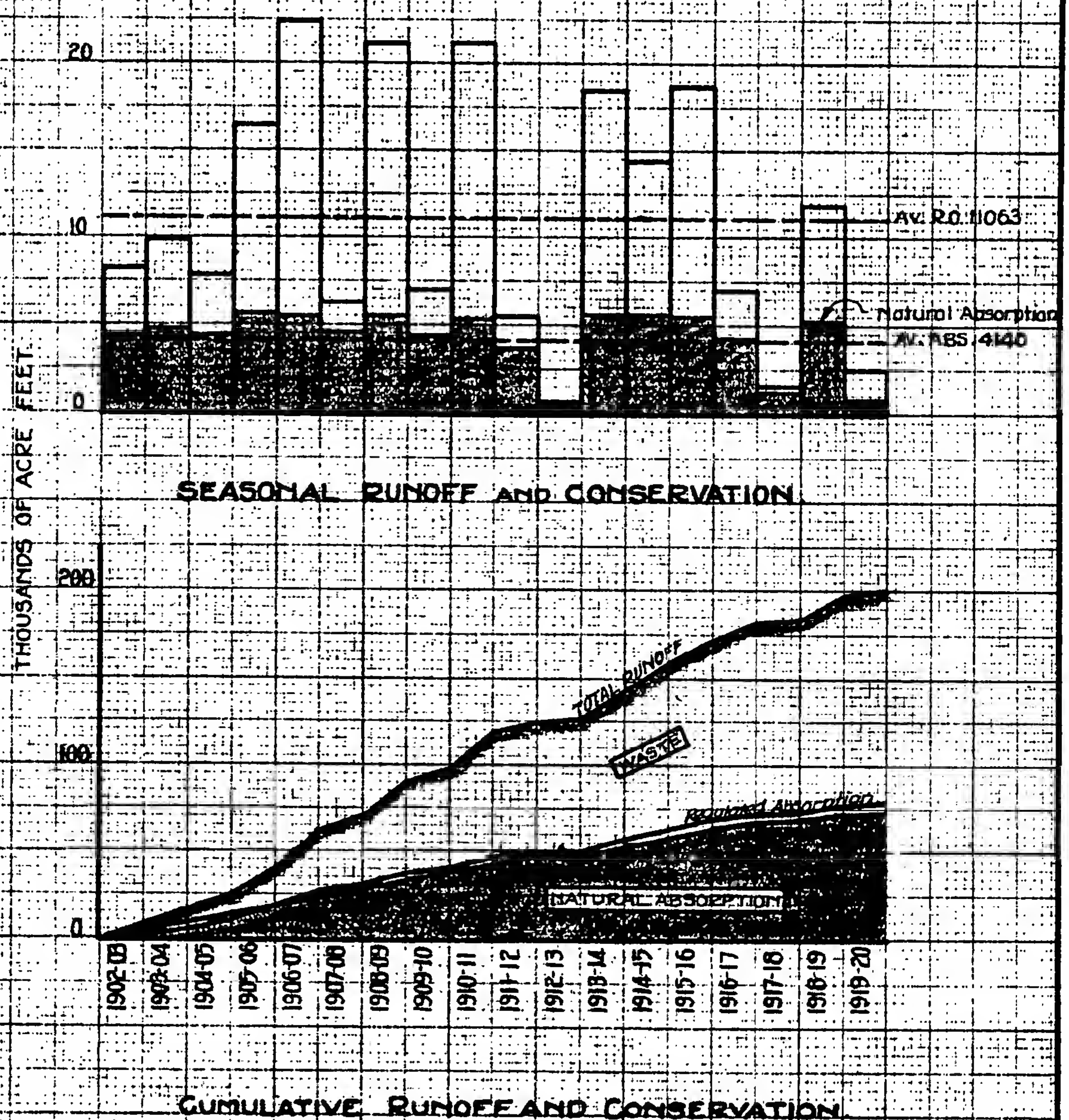
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.

SAN ANTONIO CREEK
RUNOFF AND CONSERVATION

Fred H. Tibbetts — CONS. ENG'R.
Stephen E. Kieffer — CONS. ENGR.

March. 1921

PLATE 21



NOTES

Runoff includes all of the Madera and ½ of Los Trancos and San Francisquito Creeks.

Natural Absorption based upon actual conditions during last 18 year period.

Conservable water based upon runoff as reduced by proposed storage (6480 Ac.ft.per yr.) by Stanford University.

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

MADERA, LOS TRANCOS
SAN FRANCISQUITO CREEKS

RUNOFF AND CONSERVATION

Fred H. Tibbetts, Cons. Eng'r
Stephen E. Kieffer, Cons. Eng'r

March 1921.

TABLE 12.

DISTRIBUTION OF AVERAGE ANNUAL RUNOFF (18 YEAR PERIOD)

SECTION	Mean Seasonal Runoff 18 yr. Period Ac.Ft.	% of Total entering Valley North of Upper Gorge of Coyote	% of Total entering Valley South of Upper Gorge of Coyote	% of Total entering entire Valley
Main Valley North of Upper Gorge of Coyote, tributary to S.F. Bay				
East Side - Milpitas to Lower Gorge of Coyote (Areas 1-11)	18365	8.13		6.86
		8.13		
South Side				
Coyote-Above Upper Gorge (12)	80380	35.52		30.02
" -Below " (12a,b,d)	2565	1.13		.96
Alamitos (15)	12960	5.76		4.84
Guadalupe (16)	6810	3.02		2.54
Miscel. (12c,18)	1285	.57		.48
		46.00		
West Side				
Los Gatos (17)	42330	18.75		15.81
San Tomas (19)	2100	.94		.78
Campbell (20)	11880	5.26		4.43
Calabazas (21)	1650	.73		.61
Stevens (23)	19110	8.45		7.14
Permanente (24)	2785	1.28		1.07
San Antonio (26)	1745	.90		.65
Madera (27)	1085	.48		.40
San Francisquito-Los Trancos (28)	19955	8.87		7.46
Miscel. (22,25)	470	.21		.17
Total North of Upper Gorge	225475	45.87		
		100.00		
Valley South of Upper Gorge of Coyote:				
Uvas (13)	27440		64.89	10.25
Llagas (14)	11030		25.74	4.06
Miscel. (14a,b,c)	3960		9.37	1.47
Total South of Upper Gorge	42430		100.00	
Grand Total For Valley	267905			100.00

AVAILABLE RUNOFF

The annual distribution of the average runoff covers a very wide range. The maximum for the 18 year period was reached in 1906-7 with 542,405 ac. ft., and the minimum in 1912-13 with 24,425 ac. ft. for the entire Valley. That portion for the Main Valley North of the Lower Gorge was 458,255 ac. ft. maximum, and 19,280 ac. ft. minimum. It therefore appears that the total maximum seasonal runoff is 22 times the minimum, and the average is only about one half the maximum and eleven times the minimum. The seasonal distribution is also very uneven, but typically Californian. An analysis of the gauged Coyote runoff over a period of eleven years shows an average of 81.8% of the total runoff occurred during the three months of January, February and March, and 95.5% during the months from December to April, inclusive.

It is reasonable to assume from actual observation and common knowledge of coincident stream flow, that the Coyote is typical in this respect of the other streams entering the Valley.

Because of this great annual variation in the runoff, and the fact that approximately 95% of this occurs during the winter months when there is little or no irrigation, it follows that there must be a very great waste of water and loss from beneficial use, as long as the streams are uncontrolled by storage in any form. At the present time only that water diverted in small part by surface ditches during spring flow of the streams, or that which finds its way to the underground gravels, and is later made available by pumps, is put to beneficial use, and the balance escapes to the sea. This situation, and its vital effect upon the future of the Santa Clara Valley, was recognized by Judge Welch in his decision in the case of Hayes-Chynoweth Co. vs. Bay Cities Water Co., in which he says, "The land

and householder from Palo Alto to Gilroy will be affected beneficially or detrimentally according to whether the judgment of this Court will permit the immense volume of storm waters of the Coyote to be conserved and put to a beneficial, needed use, or decides that these waters shall run to waste and be lost in the sea". After specifying in detail the method of water replenishment of the Coyote gravels, the Court provides for utilization of waste flood waters by storage for the benefit of the Valley at large. In view of the bearing of this decision upon the question of available surplus Coyote storm waters for general use in the Valley, this ruling of the Court will be referred to in detail later under discussion of storage conservation. What is said of the Coyote applies in kind, but in varying degree to every stream entering the Valley.

NATURAL UNDERGROUND WATER SUPPLY

GRAVEL BEDS

Underlying the agricultural areas of Santa Clara Valley are irregular and frequently discontinuous bodies of gravel, sand, and silt deposited by the wandering courses of the various streams draining the surrounding mountains. Between the gravel, stones, grains of sand, and particles of silt or clay, are irregular void spaces, aggregating from 10 to 50% of the total volume. A portion of the resulting porosity is available as storage and channel space for underground water, and it is from underground water bodies created in this manner that the well supply of the Valley used for irrigation is drawn. This underground water supply should be considered partly as a vast reservoir under-lying the entire valley, and partly as a very slowly and irregularly moving body of water generally flowing northerly or northwesterly towards San Francisco Bay (See Plate 23). Compilation and study of the logs of 548 wells


SAN MATEO COUNTY
SAN FRANCISCO BAY
ALAMEDA COUNTY
SAN BENITO COUNTY
LEGEND
Less than 50 feet depth to ground water. Sept. 1, 1920.
50 to 100 feet depth to ground water. Sept. 1, 1920.
Over 100 feet depth to ground water. Sept. 1, 1920.
Irrigation Well
House Well.
Observation Well.
Well with log.
Line of Geologic Section
Surface Contours
Ground water contours of Sept. 1, 1920.
Ground water contours of Feb. 15, 1920.
SANTA CLARA VALLEY WATER CONSERVATION PROJECT
GROUND WATER RESOURCES
PUMPING PLANTS AND CONTOURS AND DEPTH OF GROUND WATER
SANTA CLARA CO., CALIF.
U.S.G.S. Datum.
Contour Interval 5 Feet.
Scale
Fred H. Tibbetts. CONS. ENGR.
Stephen E. Kieffer. CONS. ENG'R.
March 1921.
PLATE 23

distributed as uniformly as possible throughout the Valley, shows a general gravel formation, sloping more or less uniformly downward toward the Bay, and overlaid as it approaches the Bay with banks of Clay of increasing thickness. (See Plates 24 and 25). The gravel beds are more or less discontinuous and are very irregular both in thickness and in shape, being separated by irregular strata of clay, silt, sand, etc.

AVAILABLE POROSITY

In an underground water reservoir such as that underlying Santa Clara Valley, the amount of water which can be recovered by lowering the water plane any given amount varies directly with the available porosity of the water-bearing materials. The total porosity of any soil or gravel formation is the ratio between the aggregate void space and the total volume of the material. This ratio may ordinarily vary in nature from about 10% to 50% or more. It depends chiefly upon the relative sizes of different grains composing the material. If these are well sorted, the void spaces between the larger grains will be nearly filled with smaller grains which in turn will be separated by still smaller grains and the resultant total porosity will be small. This is apt to be the case with material deposited by running streams in midcourse, or at moderate velocities. Material with uniform size grains such as fine clay deposited under water will have large total porosity frequently as high as 50%, but will permanently retain most of its water content. The "available porosity" of such material or the amounts of water that is is capable of alternately absorbing and relinquishing to pumps is quite small.

A vast amount of scientific investigation is available on formations similar to Santa Clara Valley, including very intensive studies in

Livermore Valley and in Southern California, and a study of "Ground Water for Irrigation in the Morgan Hill Area by O. W. Clark, 1917, (Water Supply Paper, 400-E, of the U. S. Geological Survey). This report is an authoritative study of an important and a representative portion of the proposed Irrigation District, and after careful review, the present analysis of available porosity in Santa Clara Valley underground water bodies is based on the methods outlined in the Government Report.

On Page 82 of this report is the following:

> "The vital question in this connection is not so much the total porosity of the materials and the total quantity of ground water present as the quantity of water that these materials will yield under a pump. Different materials by no means give up water to a pump in the proportion of the total water they contain. Fine materials are usually better sorted than coarser materials, and therefore when saturated they may contain even more water than the coarser materials, but they permanently retain a large percentage of this water, whereas the coarser materials readily part with a large percentage of their water content. The fine materials are therefore of comparatively little value as water producers and the coarse materials are the important water-bearing formations."

In order to estimate the available porosity of the water-bearing materials of the large West Side Division of the District, the logs of 52 wells were selected from among 380 which had been collected. These 52 wells were as uniformly distributed over the West Side Division as possible, and are believed to be representative. The top material was rejected as not lying within the range of well fluctuations. There remained a total of 8,398 lineal feet of well logs, or an average of about 160 feet per well. The material was grouped under three main headings, Gravel and Sand, Gravelly or Sandy Clay, and Clay. It is estimated that the total porosity of the Gravel and Sand is 35% of its volume, and that it will permanently retain but 10% of its water content, making its available porosity 90% of 35%, or about 31½%. The material

classified as Gravelly or Sandy Clay is probably well assorted and unusually dense, with grains varying widely in size. It is estimated that the total porosity of this material is 25% and that 90% will be retained, leaving an available porosity of 2½%. Much of the Clay more nearly resembles a Clay Loam with a wider range in size of soil grains, and hence a smaller total porosity than a true Clay. The total porosity of this material will be taken as 32%, and the available porosity as 3.2% as estimated by Clark in the Government Report quoted above.

Based upon the above deductions, the following Table 13 indicates that the resultant, average, available porosity of the Santa Clara Valley Water Bearing Formations, as typified by the West Side Division, is 11.1%. This means that for every 1 foot of water withdrawn, the water plane will be lowered about 9 feet, unless replenishments have simultaneously occurred.

TABLE 13.

AVAILABLE POROSITY (AVERAGE OF 52 WELL LOGS)

MATERIAL	AGGREGATE LENGTH	PROPORTION OF TOTAL LENGTH	TOTAL POROSITY	AVAILABLE POROSITY	PROPORTION OF TOTAL FORMAT'N
Gravel and Sand	2393 ft.	28.5%	35%	31½%	9.0%
Gravelly and Sandy Clay	2273 "	27.1%	25%	2½%	0.7%
Clay	3733	44.4%	32%	3.2%	1.4%
TOTAL	8398	100.0%	-	-	11.1%

Similar analysis in the Clark Report gives the available porosity of the Morgan Hill area in the Coyote and Morgan Hill Divisions of the District as 12.06%.

REPLENISHMENT OF UNDERGROUND WATER

SOURCE OF REPLENISHMENT

It can be assumed as evident that the bulk of the precipitation on the Valley floor during the winter is absorbed by the surface soil layers, and in the agricultural areas, is disposed of during the following season by surface evaporation and plant transpiration, the latter factor representing the water actually used by the trees and other agricultural products, and that relatively negligable portions of this precipitation reach the underground source of supply from which the wells derive their water.

The geology of the entire San Francisco Bay region, clearly indicates at once that there is no reasonable possibility of any of the underground water of the Santa Clara Valley coming from any distant source.

Practically the entire supply then of the underground water basins which feed the wells so extensively used for irrigation in Santa Clara Valley is derived from percolation from the stream beds flowing through the Valley, and frequently directly continuous with the underground gravel beds, especially towards the margin of the Valley.

STREAM BED ABSORPTION

Factors of Analytical Determination: The total amount of water normally passed into the underground gravels from each of the stream-beds is capable of fairly accurate analysis, although such analysis requires a large amount of complicated and detailed field and office work. A complete estimate of the total amounts of water which naturally replenishes the underground gravel beds, and which theoretically could be recovered by the complete development of pumping plants, has formed one of the important lines of investigation of the present report. There are three basic factors involved in such an investigation.

__First:__ The total flow of each stream into the Valley and for more detailed work, the daily or at least the average monthly flow; this factor having been deduced in the first portion of this chapter.

__Second:__ The areas in each stream bed naturally exposed to absorption. This factor has been determined from detailed field surveys of each stream, and a careful reconnaissance of the character of each, by the writers.

__Third:__ The unit rate (depth per day, or acre feet per acre per day) at which the gravel beds in the streams are capable of absorbing stream flow and passing it on to the underground gravel reservoirs. This last factor has been estimated from numerous measurements on different streams, of the actual amounts of water lost during the passage of the stream flows down measured portions of the creek beds.

__Rate of Absorption:__ The character of the different creek beds in the Santa Clara Valley varies widely. The type which is most frequent, and on many streams is found exclusively, is a stream bed with an especially regular cross section, having sides so steep that they are nearly vertical, and from 5 to 20 or more feet in depth, the bottom being covered with a layer of gravel. This is essentially the only type of stream beds around the western margin of the Valley (Figs. 12, 13, and 14) from the northern end of the District as far South as the Los Gatos Creek. For the purpose of estimating stream absorption, the areas exposed to absorption in this type of creek bed, and hence the rate at which absorption may take place, vary practically as the length of stream bed down which there is a flow of water. Plates 17 to 22 inclusive, show curves of the total amount of absorption which can take place in such stream beds. This absorption tends to vary uniformly with the discharge at the margin of the

FIG. 9.

Coyote Creek bed 3 miles below Narrows. Characteristic absorptive area.

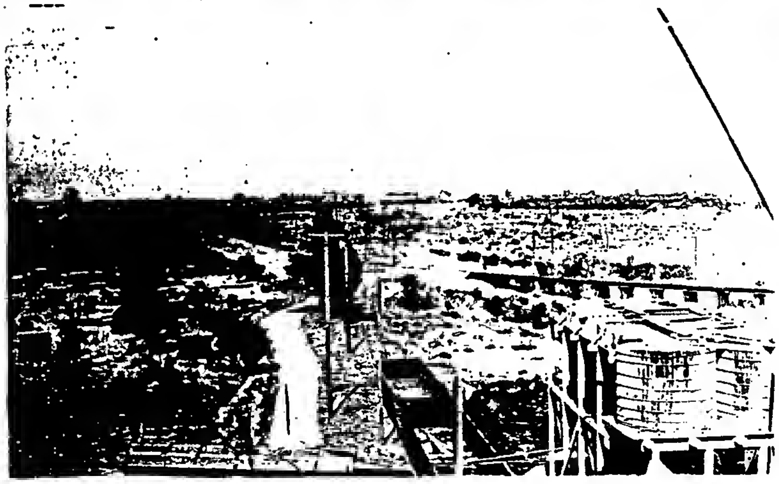


FIG. 10.

Gravel beds of Los Gatos above Campbell.

FIG.11.

Waste water at Page Dam. Los Gatos Creek.

FIG.12

Waste Water Sorosis Dam-Campbell Creek.

FIG.13

Stevens
Creek
Road.
1-29-21

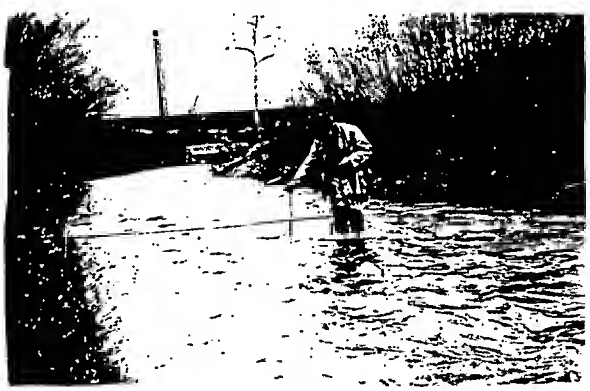


FIG.1

erri-
man
road.

Measuring seepage losses from Campbell Creek. 1-29-20

Valley, until this discharge is sufficient to cause stream flow as far as the mouth of the stream, or as far as the lower probable limit of absorption, generally taken in these creeks as about the location of the Southern Pacific Railroad because below that location the slope of the surface is much decreased, the material is a relatively impervious clay, and the ground water is close to the surface. The maximum rate of absorption is equal to the maximum amount of stream flow which can be absorbed, and the rate of absorption is practically constant with any increased flow, becoming, of course, a decreasing percentage of the total flow, beyond this point.

The Los Gatos, Guadalupe, and Coyote Creeks have stream-beds with characteristics quite different from the group described. In many places the banks are low, and the bottoms rounded and irregular, with flat lateral slopes. The total areas submerged in these stream-beds varies greatly with the amount of flow in the creeks, and the consequent change in depth. Special detailed surveys were made of each of these creek beds with frequent cross sections throughout their entire courses through the Valley. Laborious work is required in both field and office, but it has been possible to finally plot special curves showing the total absorption in each stream bed in terms of the discharge at the rim of the Valley. The Los Gatos Creek in particular at the Town of Campbell (Figs. 10 and 11) has removed by flood erosion, a large area of surface material so that its bed suddenly expands in width (Plate 68) and at moderate or high rates of stream discharge the areas exposed to percolation are greatly increased.

TOTAL ABSORPTION

Careful estimates have been made of the total amount which each stream bed could absorb, and thus beneficially dispose of, by estimating the average daily flow over the total 18 year period studied. The proportion of each days flow thus estimated which would naturally be absorbed in the stream bed and the portion which would be passed on into the Bay and wasted, has been determined, and the aggregate of all the absorbed portions gives the natural absorption in acre feet for each of the stream beds, during the periods studied, the remainder being the portion of each stream discharge naturally wasted. In actual practice it is not necessary to get the daily discharge of each stream, as a factor was used which enables the determination of the conserved and wasted portions of each stream flow, from monthly average discharges. This ratio was determined by a careful analysys of daily and monthly averages on Coyote Creek for the period of 1902 to 1914 during which such data is available.

MEASURED ABSORPTION IN COYOTE CREEK

During seven seasons of the period from 1902 to 1918, the Bay City Water Co. carefully measured the actual absorption in the gravel beds of the Coyote Creek (Fig. 9) from the upper gorge to Julian Street, San Jose. Below Julian Street it is assumed that there is no absorption from the creek bed as the bottom of the creek is generally ~~above~~ below the ground water level, and the flow of the creek as determined by summer measurements tends to increase rather than to decrease. The results of the actual measurements for seven different seasons are shown in the following Table 14.

TABLE 14.

RELATION OF COYOTE RUNOFF TO GRAVEL ABSORPTION

SEASON	RUNOFF AC.FT.	GRAVEL ABSORPTION TO JULIAN ST. Ac. Ft.	WASTE TO BAY Ac. Ft.	WASTE IN % OF TOTAL
1902-3	83,000	20,700 *	61,900	74.5
1903-4	36,500	17,400 *	22,000	60.2
1904-5	32,000	19,700 *	13,400	42.0
1905-6	116,400	24,900 *	99,500	85.3
1906-7	202,000	30,800 *	190,000	78.7
1916-17	69,900	19,300	50,600	72.4
1917-18	12,270	10,650	1,620	13.2
MEAN	78,900	20,500	62,700	79.4
18 YEAR MEAN	80,380	20,560	61,500	76.5

* Adjustments made for water entering from Laguna Seca.

It will be noted that the range of absorption is limited, and fairly constant as compared with the runoff. The year 1906-07, with 190,000 ac. ft. more runoff than in 1917-18 only shows an increase of 20,000 ac. ft. of absorption. This is due to the rapidity with which the floods pass over the stream bed. Absorption can only be increased, and waste cut by retarding the stream flow through the agency of surface storage reservoirs or check or spreading dams in stream beds.

The effect of retarded and uniform stream flow is clearly demonstrated by comparison of the records of two floods in the Coyote. In passing from the upper gorge to the lower gorge, a distance of eight miles, a flood of 454 million gallons occupied 1.58 days in passing, and lost 160 million gallons by stream absorption. A flood of 378 million gallons occupied 2.34 days in passing, and lost 190 million gallons by

absorption. Here the smaller flood with but 83% of the volume lost 20% more water than the larger flood, because its time of passage was 1-1/2 times longer.

Under present conditions the range of natural absorption on the Coyote as between minimum and maximum flow appears to be from one-sixth to one and one-half times the average.

The final summary of all these studies is shown in the following Table 15. The maximum, minimum and average seasonal Runoff and Natural Absorption for each of the eighteen years, 1902 to 1920, is tabulated for each of the 28 distinct watersheds, including all the principal creeks as well as important marginal areas which are numbered for reference purposes. (See Plates 8 and 30). In the final summary there has been excluded all of the Uvas absorption and runoff, and one-half of that of the combined Los Trancos and San Francisquito, as these areas are not in the District. The average percentage of the total runoff naturally absorbed varies from 100% for the smaller marginal areas to a minimum of 18% for the short, torential, Penitencia Creek. The average of all streams considered is 38%. Most of the larger and more important streams are well below the average, the Coyote being 25%, the Llagas being assumed as 35%, and the Los Gatos most thoroughly studied of all being 35%, or close to the average.

The results of the tabulations summarized are platted on Plates 11 to 22, inclusive.

AGGREGATE AMOUNT OF ABSORPTION

A final summary of the natural runoff and the portion of this runoff naturally conserved by stream bed absorption is shown on the frontispiece Plate 1, of this report, for all streams entering the

TABLE 15.

SUMMARY NATURAL RUNOFF AND ABSORPTION

1902-1920

STREAM	Length In Miles	Assumed Area (Acres)	Assumed Abs.Rate Sec.Ft./Ac. Average	Seasonal Runoff Ac. Ft. Max.	Min.	Aver.	Seasonal Absorption Ac. Ft. Max.	Min.	Aver.	Average Absorption %
Area No. 1				340	10	155	250	10	120	77
" 2				1280	100	625	1000	100	490	78
" 3				390	10	175	300	10	140	80
" 4				1970	150	960	1450	120	720	75
" 5				310	10	140	310	10	140	100
" 6				2980	250	1450	2200	200	1095	75
" 7				640	20	290	640	20	290	100
Penetencia Creek	25	9.0	1.0	20800	870	9920	3020	615	1770	18
Area No. 9				690	20	310	690	20	310	100
" 10				1900	80	870	1900	80	870	100
" 11				7960	150	3470	7960	150	3470	100
Coyote River				202000	3845	80380	30800	3845	20560	25
Area No. 12a & 12d				4620	110	2045	4620	110	2045	100
" 12b				1215	0	520	1215	0	520	100
Llagas				21590	1040	11030	4950	1030	3860	35
Area No. 14a				4260	135	1930	4260	135	1930	100
" 14b				3150	165	1480	3150	165	1480	100
" 14c				1220	45	550	1220	45	550	100
" 12c				770	0	335	770	0	335	100
Almaden	0.5	Variable	2.5)	36750	2840	19770	17535	2840	10585	54
Guadalupe River	7.3	"	1 to 2)							
Area No. 16				2000	120	950	2000	120	950	100
Los Gatos	9.4	"	1.0	70530	5100	42330	24475	4470	14900	35
San Tomas	8.1	17	2.17	4340	300	2100	3020	300	1550	74

TABLE 15. - Con.

SUMMARY NATURAL RUNOFF AND ABSORPTION

1902-1920

STREAM	Length In Miles	Assumed Area (Acres)	Assumed Abs.Rate Sec.Ft./Ac. Average	Seasonal Runoff Ac. Ft. Max.	Min.	Aver.	Seasonal Absorption Ac. Ft. Max.	Min.	Aver.	Average Absorption %
Campbell	6.2	24.2	2.4	19780	1410	11880	9650	1410	6000	51
Calabazas	6.0	11.2	2.2)	35240	2560	20760	12825	2560	8080	39
Stevens	6.9	33.4	1.17)							
Area No. 22				340	10	155	340	10	155	100
Permanente	2.9	4.4	1.7	5880	370	2785	1931	370	1195	43
Area No. 25				755	0	315	755	0	315	100
San Antonio	4.4	7.7	0.5	3735	195	1745	1048	195	615	35
Madero	2.0	3.0	0.5)							
Los Trancos			)	22310	590	11063	5485	285	4140	37
San Francisquito	6.1	22.	0.5)							
Total in District				479,745	20,505	230488	144,875	19,965	89,180	38
Outside District										
Uvas				42,890	3,330	27,440				
Total with Uvas				522,635	23,835	257,928+	144,875	19,965	89,180	34

+Note:-
The table includes only one-half of the total Runoff (as given for Watershed #28 in Table 11) and natural absorption on the Los Tranos and San Francisquito Creeks; such amount being assumed as tributary to the District.

District. During the 18 year period studied (1902-1920) the average aggregate annual runoff into the District was 230,488 ac. ft., and the average amount annually absorbed was 89,180 ac. ft., or about 38%. The balance of the annual runoff less the average annual amount of 13,050 ac. ft. used for gravity irrigation as shown in Chapter III, or 128,258 ac. ft., or about 55½% of the total, was the amount annually wasted into the San Francisco Bay.

The maximum range or variation in the total absorption as shown by Table 15 is much less than that of the total runoff. For the entire District the maximum annual runoff was slightly over twice the normal, and the minimum about one-eleventh of the normal. The maximum absorption was slightly greater than 1½ times the normal, and the minimum about two-ninths of the normal. Thus the maximum runoff is about 22 times the minimum, whereas the maximum absorption is only about 7 times the minimum.

The result of this ratio is, of course, to create a greater proportionate wastage during wet years, than during dry years, and hence if the last 18 years studied, is a period of less than average runoff, then the proportion of wastage is also less than normal.

The Uvas is outside the District, but the bulk of its runoff could be impounded and could then be readily diverted into the District. If its runoff be included in the summaries, then the total average annual runoff is raised to 257,928 ac. ft., 34% of which is naturally absorbed in the District, 5% used in gravity irrigation from streams, and 61% wasted.

NATURAL DEFICIENCY

Adding the natural stream absorption and the average gravity irrigation, it is concluded that for the past 18 years the portion of the water supply naturally tributary to Santa Clara Valley which did not run into the Pacific Ocean, and hence was theoretically usable, is but 102,230 ac. ft., or but 48 per cent of the total maximum requirement of 213,000 ac. ft. as deduced in the preceding Chapter.

GEOGOLOGICAL FORMATION - (Plates 24 to 27)

The floor of Santa Clara Valley, the boundaries of which are practically coincident as far South as the Town of Gilroy, with those of the proposed Irrigation District, has been built up by materials washed in from the surrounding mountains. The bulk of the work was done during the glacial period, when rainfall was much more abundant, and stream activities much more intense than at present.

It is probable that the general elevation of the Valley has been subject to repeated and important fluctuations, being at times alternately elevated above, and depressed below, sea level. The extensive and continuous masses of finely divided clay along the lower or northern end of the Valley, were presumably deposited in very quiet waters such as would have overlain this portion of the Valley when below the level of the Bay. (See Plate 24, and particularly Plate 25). The coarser materials such as gravel, sand and silt, which occur usually in smaller and more irregular and broken masses, are surface deposits from the streams. Each of these streams as it enters the Valley tends to deposit the coarser materials first, carrying the finer materials to be deposited by stream overflow farther down. See for example the upper half of Section C, Plate 24,

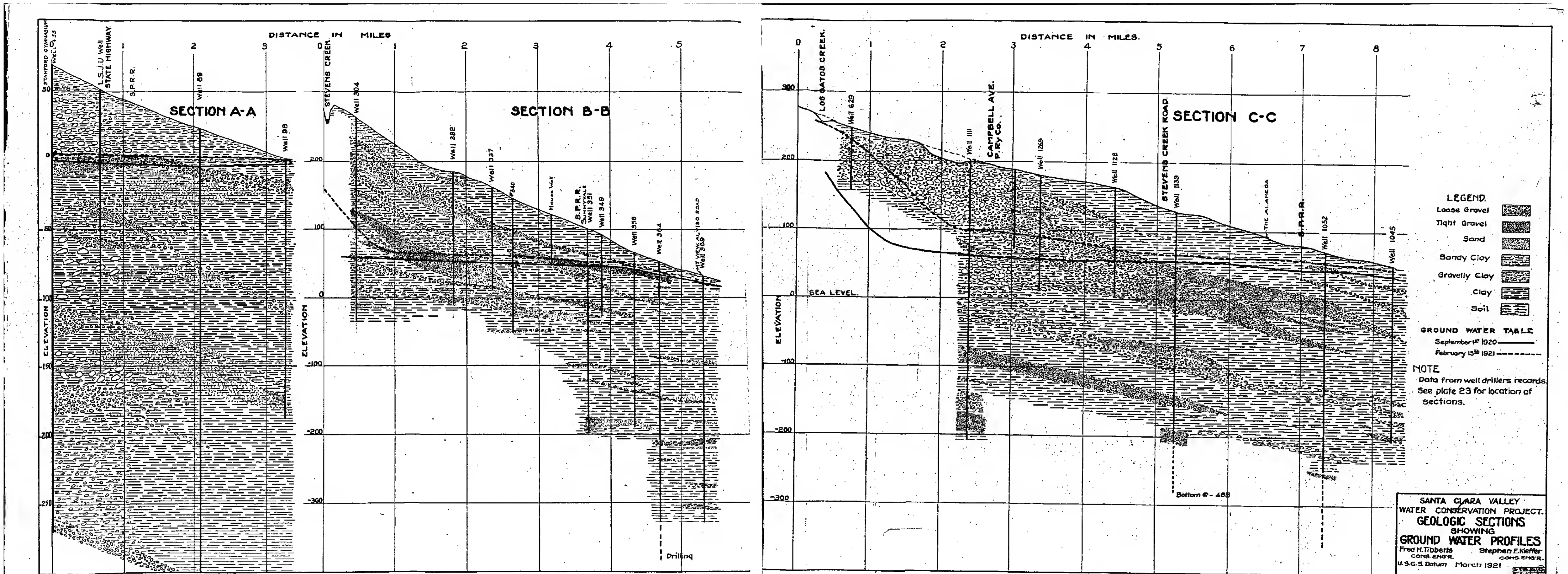
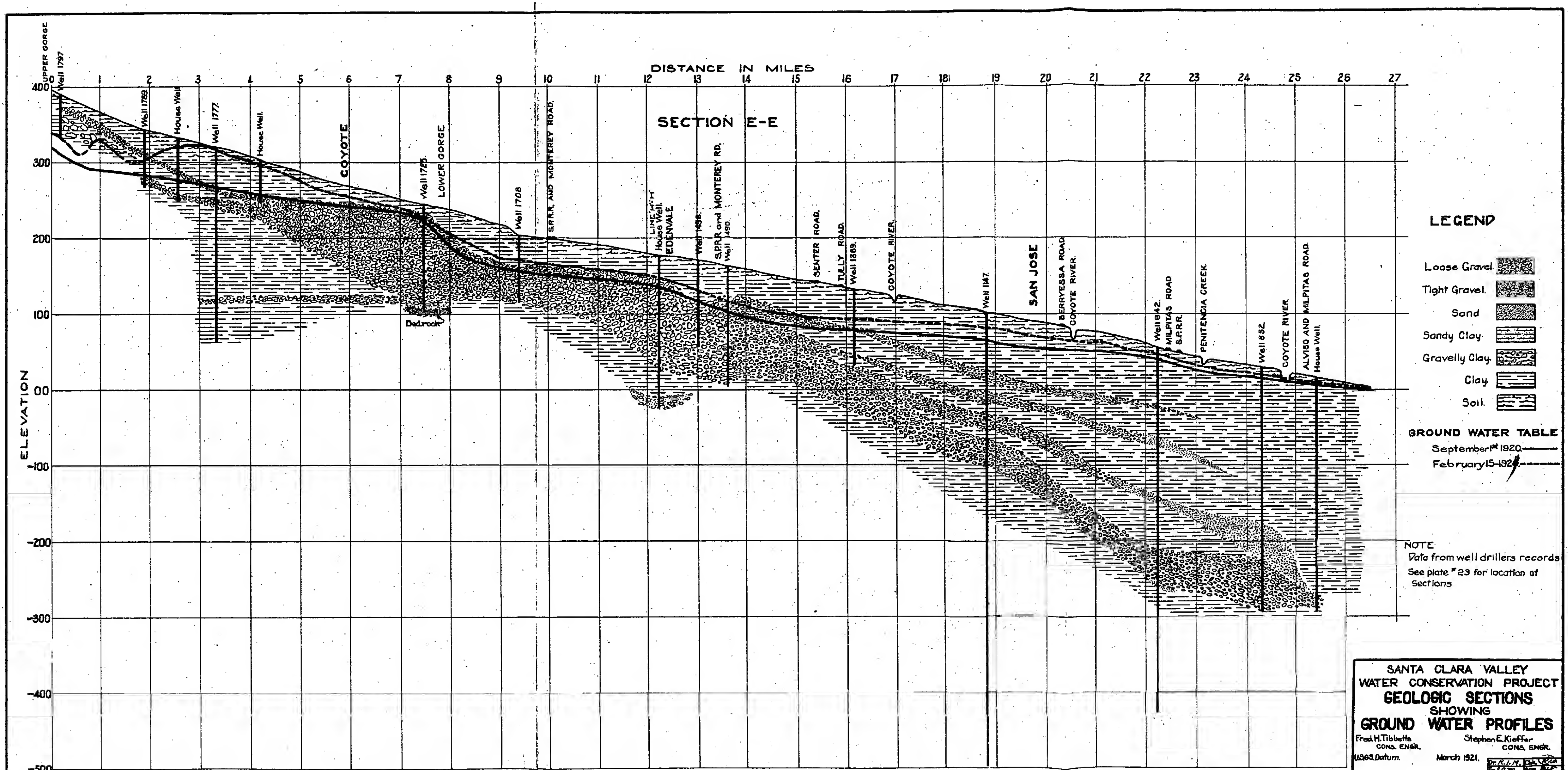
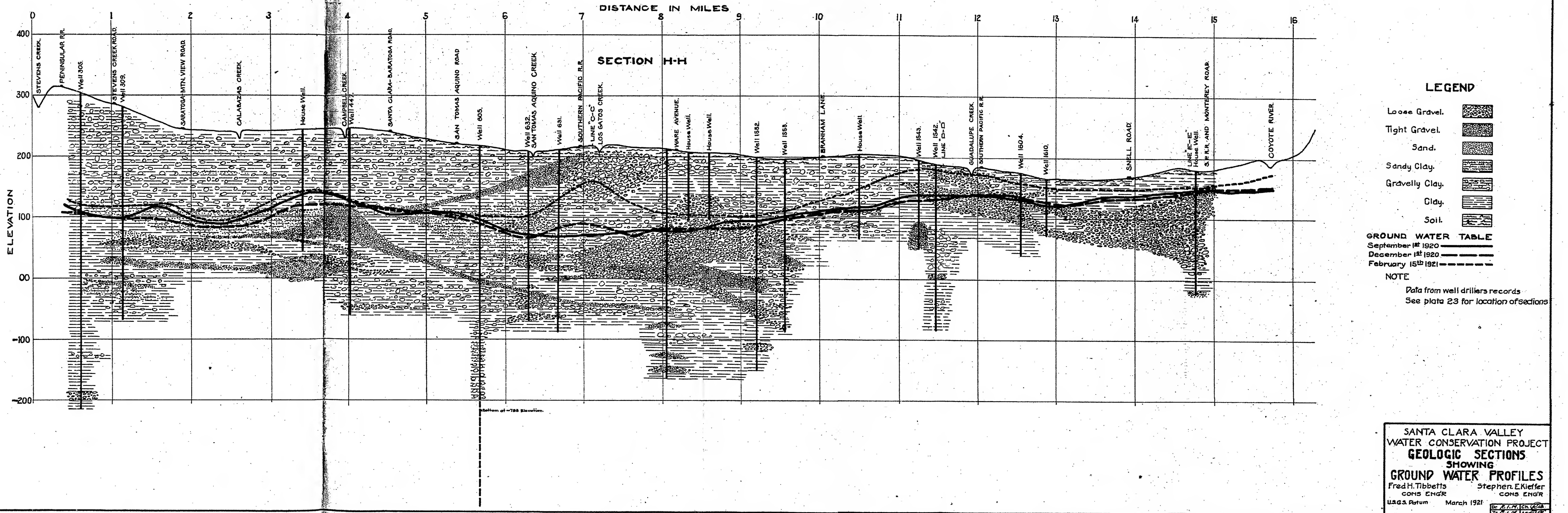

DISTANCE IN MILES
SECTION A-A
SECTION B-B
SECTION C-C
ELEVATION
SEA LEVEL.
STEVENS CREEK
LOS GATOS CREEK.
CAMPBELL AVE.
STEVENS CREEK ROAD.
THE ALAMEDA
S.P.R.R.
Well 98
Well 304
Well 382
Well 337
Well 349
Well 351
Well 629
Well 1111
Well 1128
Well 1139
Well 1052
Well 1045
Bottom @ - 488
Drilling
LEGEND.
Loose Gravel
Tight Gravel
Sand
Sandy Clay
Gravelly Clay
Clay
Soil
GROUND WATER TABLE
September 1st 1920
February 15th 1921
NOTE
Data from well drillers records.
See plate 23 for location of sections.
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.
GEOLOGIC SECTIONS
SHOWING
GROUND WATER PROFILES
Fred H. Tibbetts
CONS. ENG'R.
Stephen E. Kieffer
CONS. ENG'R.
U.S.G.S. Datum
March 1921

PLATE 24



SECTION E-E
DISTANCE IN MILES
ELEVATION
UPPER GORGE
Well 1797
Well 1789
House Well
Well 1777
House Well
COYOTE
Well 1725
LOWER GORGE
Bedrock
Well 1708
S.P.R.R. AND MONTEREY ROAD
LINE "H" House Well
EDENVALE
Well 1486
S.P.R.R. and MONTEREY RD.
Well 1490
SENTER ROAD
TULLY ROAD
Well 1889
COYOTE RIVER
Well 1147
SAN JOSE
BERRYESSA ROAD
COYOTE RIVER
Well 842
MILPITAS ROAD
S.P.R.R.
PENITENCIA CREEK
Well 852
COYOTE RIVER
ALVISO AND MILPITAS ROAD
House Well
LEGEND
Loose Gravel
Tight Gravel
Sand
Sandy Clay
Gravelly Clay
Clay
Soil
GROUND WATER TABLE
September 1st 1920
February 15-1921
NOTE
Data from well drillers records
See plate # 23 for location of sections
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
GEOLOGIC SECTIONS
SHOWING
GROUND WATER PROFILES
Fred. H. Tibbetts CONS. ENGR.
Stephen E. Kieffer CONS. ENGR.
U.S.G.S. Datum.
March 1921.



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
GEOLOGIC SECTIONS
SHOWING
GROUND WATER PROFILES

Fred H. Tibbetts, Cons. Eng'r — Stephen E. Kieffer, Cons. Eng'r

U.S.G.S. Datum — March 1921

PLATE 26

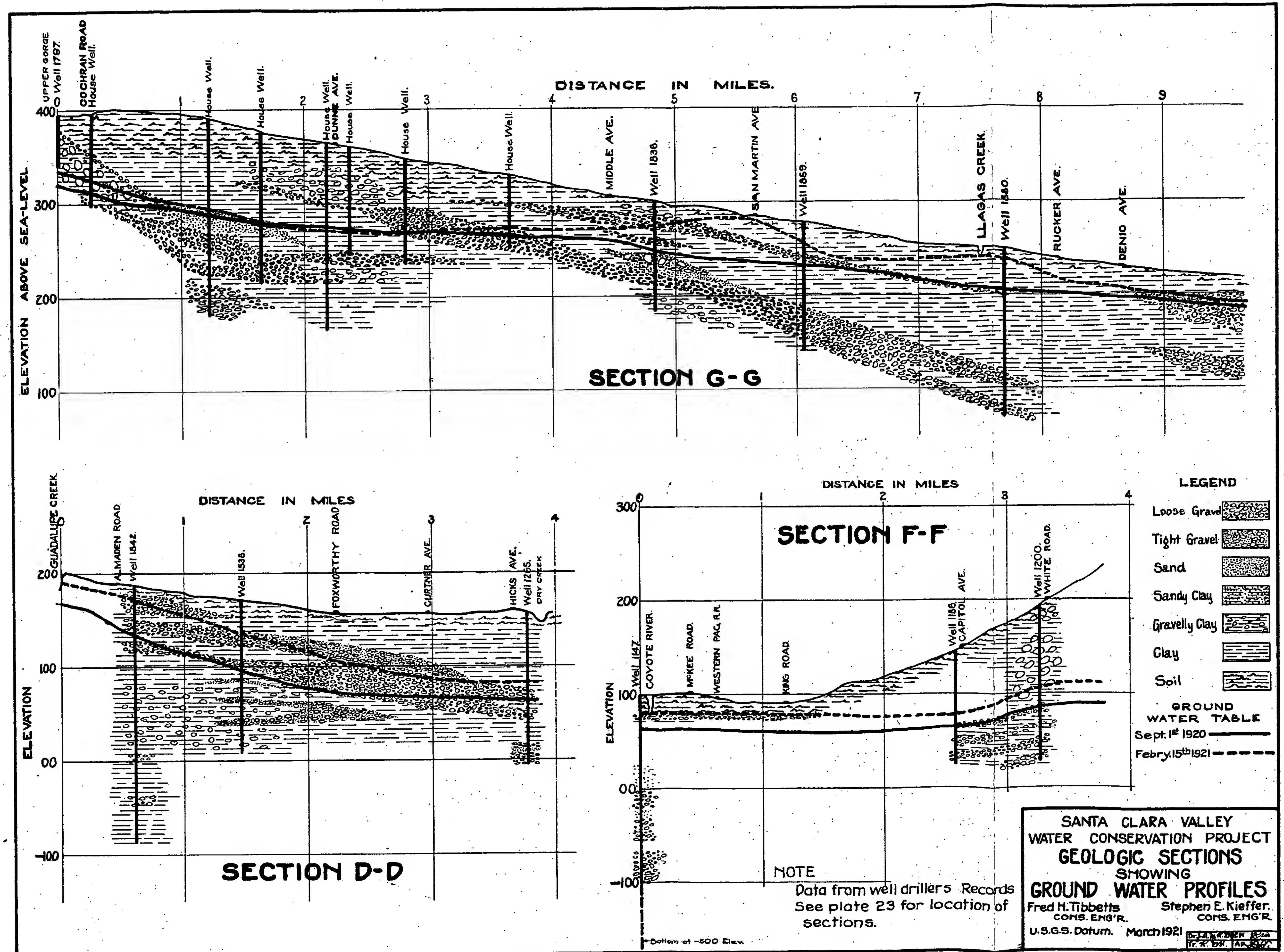

DISTANCE IN MILES.
ELEVATION ABOVE SEA-LEVEL
UPPER GORGE
Well 1787.
COCHRAN ROAD
House Well.
House Well.
House Well.
House Well.
DUNNE AVE.
House Well.
House Well.
House Well.
MIDDLE AVE.
Well 1836.
SAN MARTIN AVE.
Well 1859.
LLAGAS CREEK
Well 1880.
RUCKER AVE.
DENIO AVE.
SECTION G-G
DISTANCE IN MILES
ELEVATION
GUADALUPE CREEK.
ALMADEN ROAD
Well 1542.
Well 1538.
FOXWORTHY ROAD
CURTNER AVE.
HICKS AVE.
Well 1265.
DRY CREEK
SECTION D-D
DISTANCE IN MILES
SECTION F-F
ELEVATION
Well 1147.
COYOTE RIVER.
McKEE ROAD.
WESTERN PAC. R.R.
KING ROAD.
Well 1186.
CAPITOL AVE.
Well 1200.
WHITE ROAD.
Bottom at -500 Elev.
LEGEND
Loose Gravel
Tight Gravel
Sand
Sandy Clay
Gravelly Clay
Clay
Soil
GROUND WATER TABLE
Sept. 1st 1920
Febry. 15th 1921
NOTE
Data from well drillers Records
See plate 23 for location of sections.
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
GEOLOGIC SECTIONS
SHOWING
GROUND WATER PROFILES
Fred H. Tibbetts
CONS. ENG'R.
Stephen E. Kieffer.
CONS. ENG'R.
U.S.G.S. Datum.
March 1921

PLATE 27

which approximately follows the Los Gatos Creek. Each of these streams has thus tended to build up its own gravel or debris cone at the margin of the Valley.

WATER BEARING MATERIAL

During long periods of time the streams have wandered or migrated from side to side over their gravel cones, constantly forming new channels, in the beds of which as at present, were layers and beds of gravel, later overlaid or included in beds of clay or silt. Repeated action of this sort has tended to form gravel deposits in the form of long stringers extending from the main gravel cones down across the Valley in the general direction of the stream flow. (See particularly geologic sections B, C, and E, Plates 24 and 25). These long stringers of gravel marking former stream beds, are interspersed with and generally form irregular connections between larger deposits or lenses of gravel with considerable thickness at the center, and tending to thin out on all edges. The general stream action described, has been so frequently repeated that wells almost anywhere in the Valley if sunk to sufficient depth are almost certain to penetrate one or more of these gravel strata. The strata forming the principal source of well water are more or less interconnected, and particularly are more or less directly connected with the gravel cones and with the gravel in the beds of the streams, especially toward the margin of the Valley. Stream flow percolating into these gravel beds has immediate and most direct effect upon the wells nearest the streams, although the stratification is generally so irregular that the position of the water plane, especially as determined by measurements of wells in use, is frequently irregular and erratic.

SPECIAL GEOLOGICAL FEATURES

Coyote Debris Cone: There are two special features of the geology of the section which deserve special consideration. The Coyote River, which is by far the largest stream in the Santa Clara Valley, and the one upon which chief dependence must be placed for a supply of stored water, now enters the Valley at approximately the summit of the Divide, between San Francisco and Monterey Bays. This Divide has been formed by the Debris Cone of the Coyote itself, and down the center of this Debris Cone is located the division line between the Morgan Hill-Gilroy and the Coyote Divisions of the proposed Irrigation District. The Coyote River now flows northerly across the northerly slope of its debris cone. During the formation of the Valley the Coyote has repeatedly alternated its discharge between San Francisco and Monterey Bays, and it now distributes its underflow through its gravel cone, partly to the North and partly to the South (Sections E and G, Plates 25 and 27).

Artesian Belt: The second notable special feature of the Santa Clara Valley geological formation is the presence along the northern edge of a large, continuous, and close grained body of clay under which water-bearing gravel strata dip to such an extent as to naturally form an important artesian area. (Sections B and especially E, Plates 24 and 25). This area is fed in part from percolation from the Coyote River South of San Jose, in part from percolation from the beds of other streams along the western margin of Santa Clara Valley, and in part from a considerable and important out-cropping of pliocene gravels, the up-tilted edge of which is directly exposed along the western foot-hills. The gravel strata directly under the clay beds confine artesian waters under pressure. Artificial increase of percolation from the beds of the Coyote River, or

from any of the western streams, will tend to forward more water to the artesian gravels, making it possible to recover increased quantities of water from artesian wells penetrating the lower end of the artesian gravels, along the present margin of the Bay.

Projecting Spurs: In a number of places such as "Lone Hill", the group of hills South of San Jose, and adjacent to the cemeteries, the ranges of hills at the Lower Gorge of the Coyote and at the "Narrows" (Fig. 8), there are partly buried rock spurs of igneous origin projecting toward the center of the Valley. All of these appear to be generally parallel to the streams and to the slope of the present Valley surface. They tend to divide the underground water bodies into separate basins but no where to interrupt the continuity of slope of the underflow or apparently to seriously affect its movement. (Compare Plate 23).

UNDERGROUND WATER MOVEMENT

Underground water like any surface stream, always flows down hill, although the rate of such flow is exceedingly slow.

In definite underground channels through gravel or sand, the velocity of underflow under natural conditions, will ordinarily vary from 3 to 4 to perhaps 30 or 40 feet per day. In any connected body of underground water, a definite and continuous slope indicates the direction of movement, and the steepness of the slope, combined with the imperviousness of the material, is indicative of the rate of movement. In a formation so irregular and broken as that of Santa Clara Valley, the slope of the underground body of water is not uniform. The colored contour lines on the accompanying map, Plate 23, indicate the position of the underground water plane in Santa Clara Valley, first at approximately its lowest level which occurred in September 1920 shortly after the end of the irrigation

season, and the second about February 15, 1921, when approaching the crest of its annual rise. Where the slope of the water plane is steep, it is indicative of unusually rapid movement of the water, or of abnormally impervious stratification. Steep slopes are generally found around the rim of the Valley and indicate a rapid draining away of the gravel cones toward the main body of underground water from which the bulk of the well withdrawals has been taking place. Compare the water contours of Plate 23 with the water planes shown on the cross-sections B, C, and D, of Plates 24 and 27.

In general, marked changes in the direction or rate of slope of the water plane define naturally the areas receiving their underground supply from different sources. This fact has been utilized in drawing the boundary lines of the six main divisions of the proposed District. Each of these six divisions are divisions which are natural units as determined by a common source of underground water supply, or by surface topography, or as in the case of the division between the Evergreen and Milpitas units, by feasible, physical limits, of artificial supply.

During the season of 1920-21, heavy rains began in October and continued at fairly regular intervals through December and January, with somewhat less in February. Some of the creeks were flowing continuously to the Bay by the middle of December, and practically all of the important ones by the middle of January. The relative position of the two sets of contours on Plate 23 indicates the movement of the water plane at all points in the proposed District during the period from September 1920 to the middle of February 1921.

LOW WATER PLANE

Low water position contours of September 1920, clearly indicates the great influence of the large amount of pumping for irrigation. In the central portion of the Valley, particularly in the West Side area, the slope of the water plane over large areas is relatively small, and continuous and heavy pumping has apparently created large irregular depressions, basins or trough-like formations, in the surface of the low water plane. The largest of these projects northwesterly through the central portion of the West Side District, and forms an extensive area in which the depth to water in September 1920, exceeded 100 feet, as shown by the colored zones on Plate 23. Comparing the low water plane as indicated on cross sections C and H, Plates 24 and 26, it will be seen that near the intersection of the sections just above the Town of Campbell, the natural forward movement of the underground water has been sharply arrested by excessive withdrawals. The water plane is nearly level for several miles down Section C, and water is evidently being drawn from all directions into the wide depression to supply the pumping plants.

A trough in the water plane contours between the Guadalupe and Coyote Rivers, South of San Jose, indicates the division line between areas receiving underflow from the two creeks, and largely on account of this, was made the division line between the Coyote and West Side Divisions of the main Irrigation District.

HIGH WATER PLANE

The second set of underground water contours indicates the certainty and the directness of the underground water replenishments from the various creeks entering the Valley. The cross sections of Plates

24 to 27, and particularly the Section H of Plate 26, also clearly indicate the main method of replenishment of the underground bodies. During the last three of the months intervening between the two sets of contours, a more or less continuous flow in the creeks has caused a very marked rise in the water plane in the vininity of the streams, this rise diminishing generally with fair uniformity with the distance from the streams, the rise in some cases being as much as 20 to even 30 feet, and in extreme cases, 60 to 90 feet in wells close to the creek beds. The steepening of the water contours in the vicinity of the creek beds from which percolating waters are escaping, clearly indicates the direct and rapid movement of these waters toward the main body of underground water.

It must be at once obvious that as long as stream flow is maintained, water will continue to percolate from the stream beds to the underground water bodies, and that if artificial means are used to retard the flood flows which normally are wasted into the Bay, and thus to prolong percolation from the streams, the replenishment of the underground gravel beds will be increased, with a corresponding increase in the quantity of possible withdrawals, for irrigation use.

WELL FLUCTUATIONS

EFFECT OF PUMPING

The position of the underground water plane is in general fixed by measurements to the water surface in wells penetrating the underground water body, and freely connected therewith. The fluctuations in the level of the water plane are those determined directly by well measurements.

There are important limitations, however, to this method. When wells have been continuously and especially recently, pumped at the time of measurement, the water level in the wells will be lower than the normal level of the underground water body in their vicinity. Continuous pumping of a well forms a local cone of depression with the well in the center of this cone. The total amount of this depression below the general or normal ground water level, will depend upon the length of time and the rate of pumping, as well as the rate of flow through the gravel toward the well, this latter factor being a function of the size and porosity of the water-bearing medium. The extent of the depression below the notmal water plane will vary with the distance from the well, becoming increasingly less with increase in distance in all directions from the well. After the cessation of pumping, the time required for complete recovery to the normal plane will also vary with the amount of the depression, and hence the extent to which the cone of depression has been developed, as well as the size and porosity of the water-bearing medium. In the large number of well measurements taken in the course of this investigation, every reasonable effort has been made to prevent the inclusion of well measurements from wells in which pumping was in progress, or in which it had recently been in progress. In spite of this fact, there are undoubtedly many of the well measurements which are more or less effected by local pumping either in the well measured or in adjacent wells.

A much more important element in the present study is the cumulative effect upon the lowering of the general water plane, of pumping from a large number of wells. The effect of such pumping in the summer time, when due to natural causes the water plane is lowering, is to

greatly accelerate the rate and increase the extent of such lowering, and thus to accentuate the normal fluctuations of the water plane.

ANNUAL FLUCTUATIONS

Under natural conditions the water plane starts to fall as a rule during April, due to the failure of the natural source of replenishment from percolating stream beds, and to the rapidly increasing evaporation and plant transpiration, the supply for which is drawn by capillary attraction from underground water bodies. This annual drop usually continues until into December or January, the rate of drop showing marked dimunition by September, when the evaporation and transpiration losses become very small, and the annual rise beginning in December or January when stream flow becomes considerable. The amount of this annual fluctuation will vary greatly in different parts of the Valley from 4 or 5 feet up to 20 or more feet. The increased fluctuation under present irrigation conditions involving heavy withdrawals for summer irrigation from wells, will reach a maximum variation up to 50 or 60 feet, or perhaps more.

Plates 28 and 29 show such long time records of well fluctuations as are available. Unfortunately there are comparatively few such records, and these are not well distributed. Plate 28 shows three wells platted from the records of the Bay City Water Company and considered typical of the Coyote Valley South of San Jose. Two of these wells Nos. 1116 and 1739 cover the same approximate eighteen year period, 1902-1920, as used for the main Water Resources study of this report. On Plate 29 are shown five records covering from 2 to 12 years, and fairly well distributed over the West Side Division. Well No. 493 is at Lawrence, 1135 about two miles West of San Jose, 1245 at San Jose, 1111-A at Campbell, and

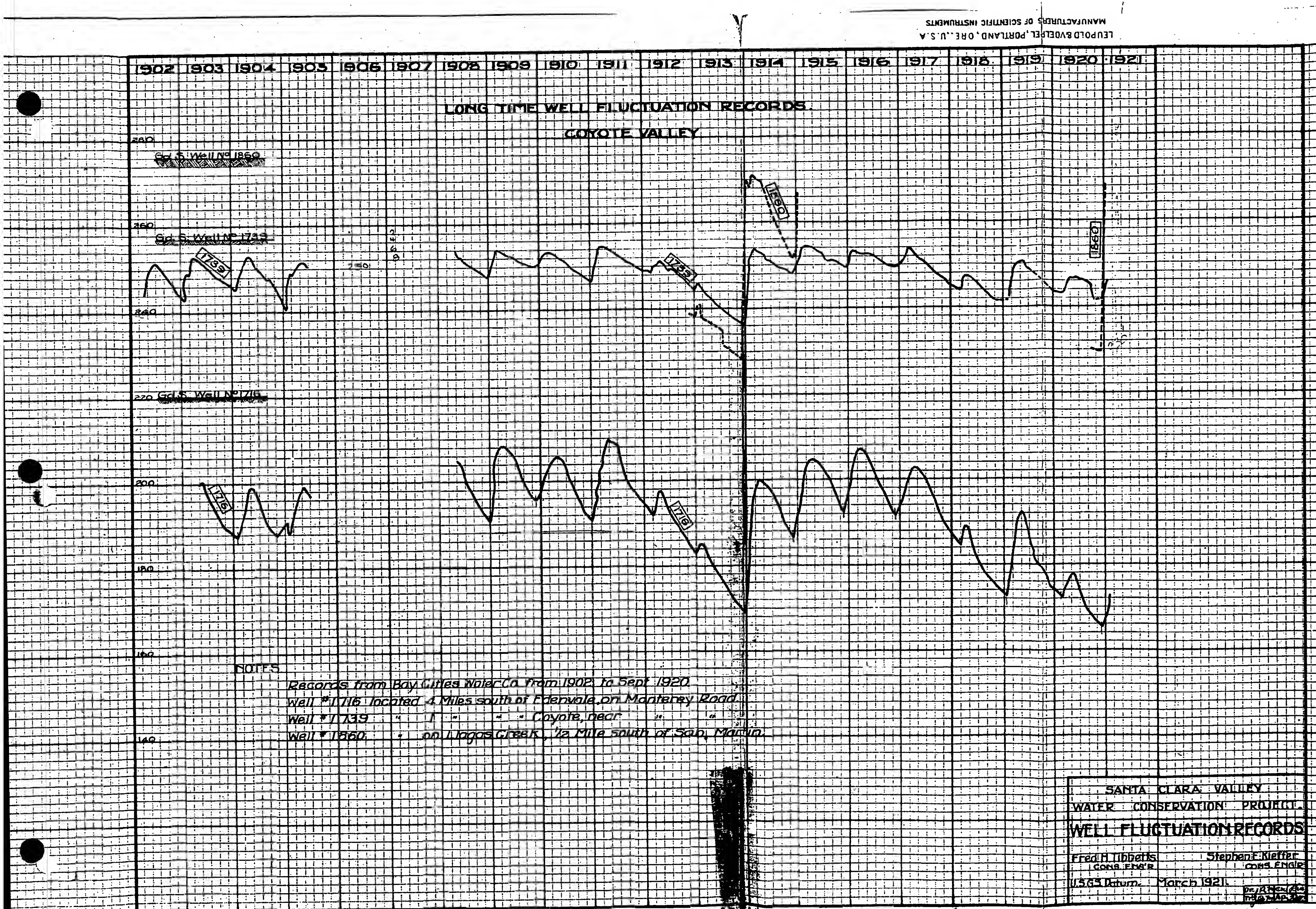

LONG TIME WELL FLUCTUATION RECORDS.
COYOTE VALLEY
1902 1903 1904 1905 1906 1907 1908 1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921
280
260
240
220
200
180
160
140
Gd. S. Well No 1860
Gd. S. Well No 1739
Gd. S. Well No 1716
1739
1716
1860
NOTES
Records from Bay Cities Water Co. from 1902 to Sept 1920.
Well #1716 located 4 Miles south of Edenvale on Monterey Road
Well #1739 " " " " Coyote, near " "
Well #1860 " on Llagas Creek, ½ Mile south of San Martin
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.
WELL FLUCTUATION RECORDS
Fred H. Tibbetts
CONS. ENG'R
Stephen E. Kieffer
CONS. ENG'R
U.S.G.S. Datum.
March 1921.
LEUPOLD & VOELPEL, PORTLAND, ORE., U.S.A.
MANUFACTURERS OF SCIENTIFIC INSTRUMENTS

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PLATE 28

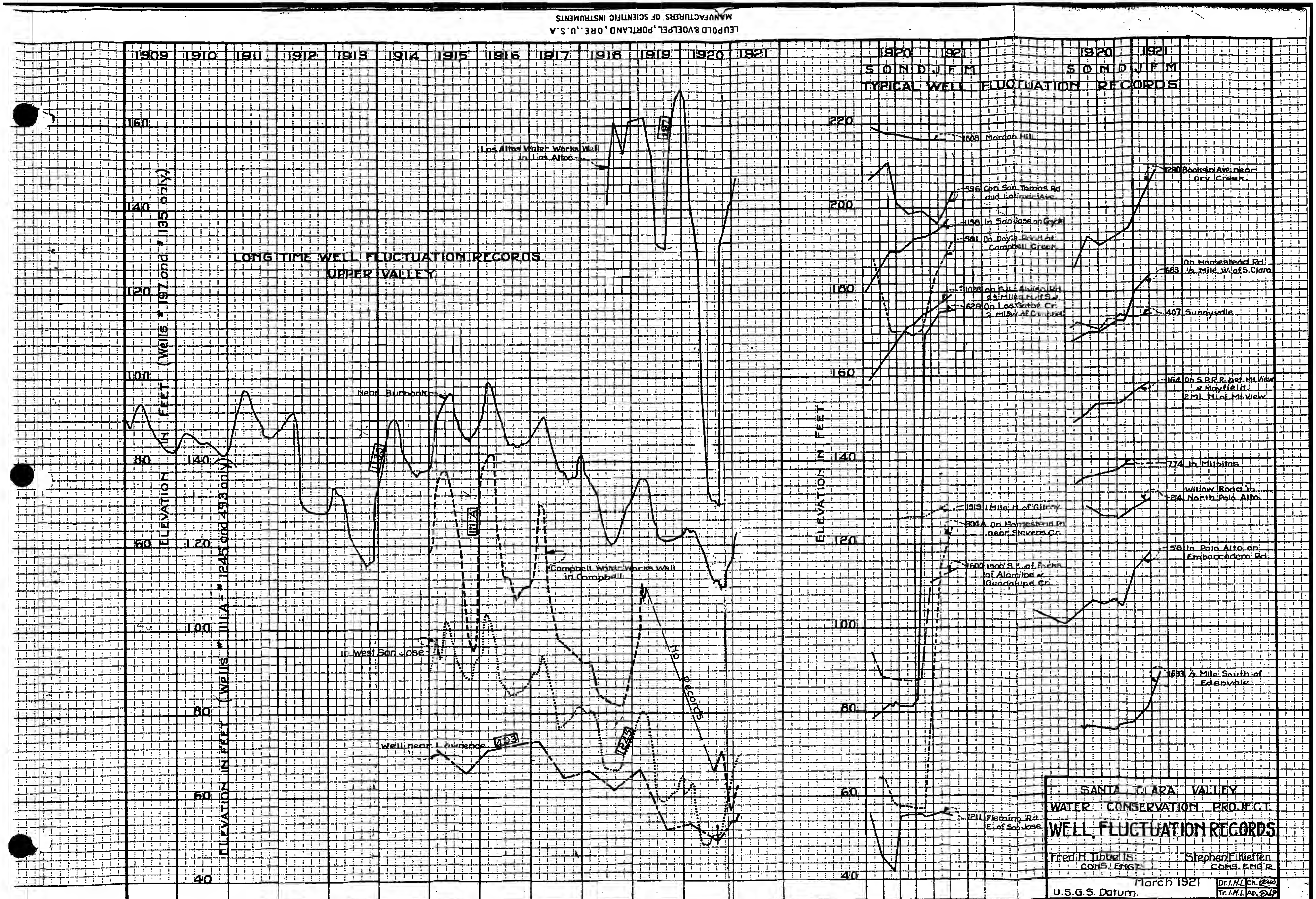

LEUPOLD & VOELPEL, PORTLAND, ORE., U.S.A
MANUFACTURERS OF SCIENTIFIC INSTRUMENTS
LONG TIME WELL FLUCTUATION RECORDS
UPPER VALLEY
1909 1910 1911 1912 1913 1914 1915 1916 1917 1918 1919 1920 1921
ELEVATION IN FEET (Wells # 197 and # 135 only)
ELEVATION IN FEET (Wells # 111A # 1245 and 493 only)
Los Altos Water Works Well in Los Altos
Near Burbank
Campbell Water Works Well in Campbell
In West San Jose
Well near Lawrence
No Records
TYPICAL WELL FLUCTUATION RECORDS
1920 1921
S O N D J F M
ELEVATION IN FEET
1608 Morgan Hill
596 Cor. San Tomas Rd and Latimer Ave.
1156 In San Jose on Coyote
561 On Doyle Road at Campbell Creek
1098 on S.J.-Alviso Rd. 2½ Miles N. of S.J.
629 On Los Gatos Cr. 2 Miles W. of Campbell
1919 1 Mile N. of Gilroy
304A On Homestead Rd near Stevens Cr.
1600 1500' S.E. of Packa of Alamitos & Guadalupe Cr.
1211 Fleming Rd E. of San Jose
1280 Bookside Ave near Dry Creek
683 On Homestead Rd ½ Mile W. of S. Clara
407 Sunnyvale
164 On S.P.R.R. bet. Mt View & Mayfield 2 Mi. N. of Mt. View
774 In Milpitas
24 Willow Road in North Palo Alto
58 In Palo Alto on Embarcadero Rd.
1683 ½ Mile South of Edenvale
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
WELL FLUCTUATION RECORDS
Fred H. Tibbetts CONS. ENGR.
Stephen E. Kieffer CONS. ENGR.
March 1921
U.S.G.S. Datum.
Dr. I.H.L. Ck. Tr. I.H.L. Ap.

PLATE 29

197 at Los Altos. All of this latter group of wells are more or less continuously pumped for water supply purposes, and hence tend to exaggerate the normal or annual movements of the general water plane. This is particularly true of the last two listed in which the great annual fluctuation indicates excessive over-draft as well as abnormally impervious water-bearing strata.

Certain very important general conclusions may be drawn from all these long term records. The annual fluctuation is clearly shown, though its amount is probably greatly exaggerated in the wells which are being heavily pumped, especially if they happen to penetrate less than the average thickness of water-bearing strata. Lowest annual levels are generally reached during September or October, and highest during March or April.

Another feature of the greatest significance is the extremely low levels of 1913 at the close of the two successive very dry seasons of 1912 and 1913. Low levels of all wells for which long time records are available were practically the same as the low levels of 1920. The following three years were years of more than normal rainfall, runoff, stream absorption, and underground water replenishment. Complete recovery is noted in all wells recorded at the high water level of 1916, and in some cases of 1917. The last four years, except 1919, have been years of subnormal rainfall, and the wells have continuously dropped, though there was a marked effort at recovery in 1919 when the rainfall was slightly above normal.

On the right half of Plate 29 are shown the graphs of 18 typical wells from measurements from September to February forming part of the field work of the present report. The time range is such as to

cover approximately the low point and in most cases nearly to the high point of the last season. These diagrams are chiefly significant in showing the great and rapid rise on the wells nearest the flowing creeks. There is also a great difference in the amount of the annual fluctuation from 4 or 5 to 70 or 80 feet, the lower wells nearest the Bay showing comparatively little difference.

EFFECT OF CREEK FLOW ON WELLS

The water plane fluctuations on Plate 26 which is a cross section of the Valley, in general normal to the creek beds, is of the greatest significance as showing the promptness and extent of the response of the fluctuating wells and of the water plane, to the percolating waters from the creek beds. The water table in the immediate vicinity of the creek beds begins to rise very shortly after the first steady stream flow, and within a month or two shows very marked peaks in the vicinity of the creek beds, extending for a distance of two to four miles from the creeks until the slopes of the water plane peaks at the stream beds intersect, forming a continuously rising water plane with the greatest rise in the vicinity of the creek beds. A comparison of the water planes of December 1, 1920, and February 15, 1921, is absolutely conclusive evidence on this point, and is one of the most important demonstrations of this entire report. This obviously indicates that if the percolating creek flows could be prolonged, the extent and amount of this annual rise could be increased so that it equaled or exceeded the annual drop during the irrigation season, and thus the continuous fall in the water plane could be checked, and it could perhaps be eventually restored to its normal condition prior to irrigation. In some Divisions of the Valley, notably in the

Coyote Division, it seems clear that this complete recovery of the water plane would occur under natural conditions, during wet or perhaps during normal years. If by supplying artificially stored water so as to prolong the rise of the water plane during dry years, then complete recovery could always be assured.

PERMANENT LOWERING OF WATER PLANE

Conclusions can now be drawn from the data of this and the two preceding chapters regarding the impending failure of the Water Resources of Santa Clara Valley unless steps be taken at once to artificially conserve the present wastage of flood water.

The summaries of Chapter III indicate that up to the time of the government report of 1912, the total area irrigated was less than one-half of that of 1920, and presumably the water used was in like proportion or was about 69,000 acre feet, or materially less than the normal replenishment as deduced above of 89,180 acre feet.

Estimating the increase of the use of water from the 69,000 acre feet of 1912 to the 136,870 acre feet of 1920, indicates that the demand did not begin to exceed the natural replenishment till about 1916 or 1917, a conclusion perfectly supported by the long term well records of Plates 28 and 29. The permanent drop in the water plane then commenced about this time for the perfectly clear reason that the demand of the wells began to exceed their supply. Fortunately it has been found possible to compute, and by a separate method to check the amount of such permanent drop, and to predict its probable future rate of continued decline, at least for the largest Division of the District, namely, the West Side Division.

The original notes of the Government 1904 well investigation have been utilized to draw water contours showing the position of the low water plane of 1904 over about 22,000 acres of the District included in the West Side Division. 1903 and 1904 were about normal rainfall and runoff years, and the position of the water plane as thus determined for 1904 may be assumed to be normal up to 1916 at the beginning of the permanent drop. A careful detailed comparison of the low water plane of 1904, assumed to also represent that of 1916, with that of 1920, shows a total average drop over this area in four years of 16.3 feet. Individual comparisons show that this drop varied from nothing in the lowest parts of the District to about 55 feet in the vicinity of Campbell and Cupertino.

An analysis for the last four years of the deficiency in water replenishment over water demands has been made separately for the West Side Division. The total water demand (Div. 73½% dev. in 1920; 49% in 1917) for the 4-yr. period, was 254,300 ac. ft., and the total natural replenishment 116,000 ac. ft., a total deficiency of 138,300 ac. ft., or an average of 1.8 feet in depth over the total area of 76,875 acres. The total drop in the water plane as previously deduced from the average porosity of 11.1% should have been nine times this amount, or 16.2 feet. The remarkably close agreement of the analytical drop thus obtained with the measured drop of 16.3 feet should leave no possible doubt regarding the fundamental accuracy of the methods used.

Following the methods of the above deductions, it is also possible to estimate with comparative confidence the probable future drop in the water plane for the entire District. The summaries of Chapters 2 and 3 indicate that the probable full development of the

Valley with corresponding maximum demand for water should be completed by the end of the next decade, or say by the end of 1930. The estimated demand for water at that time would be about 213,000 acre feet. The natural replenishment from primary sources, assuming it to continue at the average rate of the last 18 years is about 89,180 acre feet. If it be estimated that for the entire District one-third of this normal replenishment will be available for re-use,, then the total available supply will be about 117,000 acre feet, which compared with the demand of 213,000 acre feet would leave a deficiency of 96,000 acre feet, or 45% of the demand. There would then be an annual shortage of water equivalent to a depth over the entire area of 96,000 divided by the area of the District, plus 5% marginal lands, or a depth of 0.582 feet. If the available porosity were the same as deduced for the West Side Division, or 11.1%, then the average annual drop of the water plane would be 5.25 ft. If at this time there were two consecutive seasons with rainfall, runoff and absorption as subnormal as the last two seasons, then the average drop in the water plane would be 6.75 feet. Similar deductions for the West Side Division alone, based upon the average runoff of the last 18 years, indicates an average drop when fully developed (Probably in less than ten years) of 6.1 feet, and an average drop for two seasons as dry as the last two of 7.3 feet.

The most important of these conclusions are graphically shown on Plate I.

CHAPTER V.

CONSERVATION AND USE OF WATER

STORAGE RESERVOIRS

GENERAL

An important factor in the maximum utilization of the runoff from every watershed, where the flow is of seasonal and torrential character, is the possible storage of flood waters. This is particularly the case in this project, where it has been found that about 95% of the total annual runoff occurs in the nominally non-irrigating months of January, February and March, with an average loss to the sea of at least two-thirds of this flow.

A very complete reconnaissance has been made of every reservoir site in the least worthy of consideration upon the tributary watersheds of this project, a total of twenty in number. Complete stadia surveys were made of sixteen of these sites, and upon the balance maps of previous surveys were obtained. These reservoir sites are distributed upon the various watersheds and streams as follows: Coyote, 2; Uvas, 1; Llagas, 2; Calero, 2; Alamitos, 1; Guadalupe, 3; Calabazas, 1; Stevens, 3; Permanente, 2; San Antonio, 1; Madera, 2; All of these sites are on the South and West sides of the valley; there are none on the east side. For hydrographic reasons of insufficient water supply to justify construction one site each on the Llagas, Calero, and Madera have been eliminated, and for physical and economic reasons, two sites on the Guadalupe are given secondary consideration only. Maps of seventeen of these reservoirs and dam sites,

together with tentative sections and plans of dams, are herewith attached. (Plates 31 to 64 inclusive).

The following table gives the available storage, within close economic limits, of each of the reservoir sites, together with the 18 year average tributary water supply.

TABLE 16.

RESERVOIR CAPACITIES AND WATER SUPPLY

Reservoir	Area of Tributary Watershed, sq. mi.	18 yr. Aver. Annual runoff ac.ft.	Storage Cap.ac.ft. each	total	Ratio of Stg. Cap. to runoff
Coyote #1			60000		
Coyote #2	193.20	80380	60000	120000	1.50
Uvas	29.80	27440		20000	.73
Llagas	19.64	9515		20000	2.08
Calero	7.34	2205		9000	4.07#
Alamitos	10.24	6360		2500	.40#
Guadalupe #1)			2300		
Guadalupe #2)	5.66	3240	1200	3500	1.08
Guadalupe #3)	7.96	3570		3000	.84
(Calabazas)	2.33	1090		1600	1.47#
(Azule Springs)					
Stevens #1)			4000		
Stevens #2)			2000		
Stevens #3)	18.22	18130	600	6600	.36#
Permanente,S.F.	3.34	1560		1170	.75
" ,N.F.	3.30	1175		1100	.94
San Antonio	4.26	1305		1000	
Madera	3.46	510		5000	1.62#

Note: (#) Surplus storm water will be carried by conduits from Alamitos Creek to Calero Reservoir; from Stevens Creek to Calabazas Reservoir; and from Los Trancos Creek to Madera Reservoir.

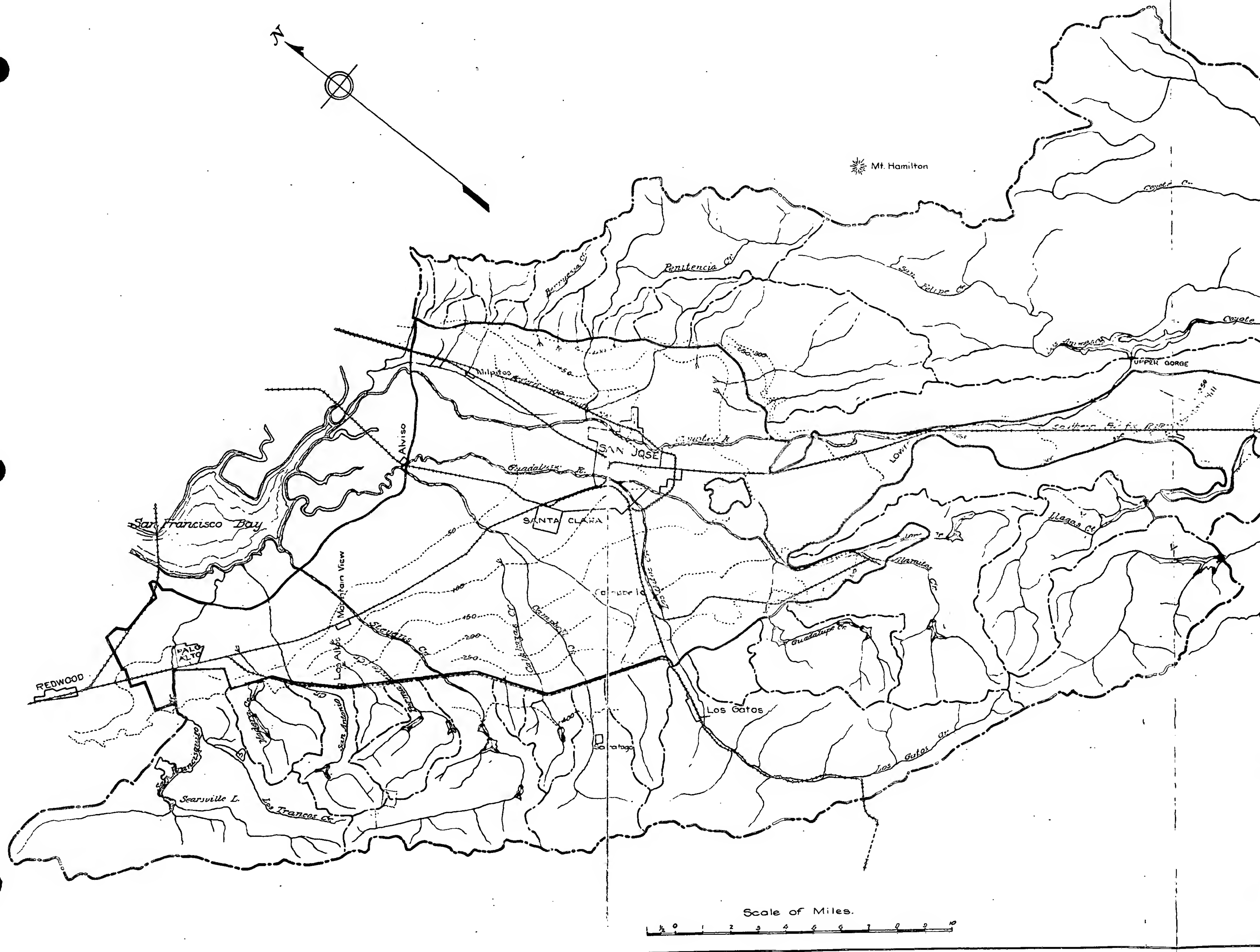
From this table it will be observed that on those streams having available reservoir sites there is a total average annual flow of 159050 acre feet (including 2570 ac. ft. from Los Trancos Creek diversion) and a total economic storage of 194,470 ac. ft. The distribution of this storage is indicated upon the attached general watershed map. (Plate 30) which shows the location of the reservoirs. It will be observed that, while for the most part the greatest amount of storage is located upon those streams having the largest volume of flow, there are two principal streams of large flow -- Los Gatos and Campbell Creeks - entirely lacking in storage sites. The East side of the valley is also entirely without storage facilities. Consequently the major portion of the water to be conserved by surface storage must be impounded upon the streams in the Southern end of the valley.

The geographical distribution of this storage, and its relation to the total is shown in the following table:-

TABLE 17.

REGIONAL DISTRIBUTION OF STORAGE

Section	Available Storage Ac. Ft.	Percent of Total
East Side-Milpitas to Lower Gorge of Coyote Creek	0	0
South Side - Upper Gorge to Guadalupe Creek	138000	71.00
West Side - Los Gatos to Palo Alto	16470	8.40
South Side - Morgan Hill-Gilroy Area	40000	20.60



MAP OF
SANTA CLARA VALLEY AND SURROUNDING WATER

Showing Irrigable Area, Principal Tributary Sites and Proposed Reservoir Sites

Investigations of
SANTA CLARA VALLEY WATER CONSERVATION COMM

Fred H. Tibbetts, Consulting Engineer.
Stephen E. Kieffer, Consulting Eng

March 1921.

PLA

DESCRIPTION OF RESERVOIR SITES AND DAM SITES

The following is a very brief description of the reservoir sites listed in Table 16 and shown upon Plate 30.

Coyote #1 (Figs. 15 & 16) (Plates 31 & 32)

Damsite is located at the point commonly known as the Upper Gorge of the Coyote, where Coyote Creek breaks through the hills into the valley. At this point there is a site suitable for a dam that will create a deep, narrow reservoir with a total length of about five miles and a capacity (with 203'depth water at dam) of 60000 acre feet.

Coyote #2 (Figs. 17 & 18) (Plates 33 & 34)

This site is located about five miles up Coyote Creek canon from the Upper Gorge. The damsite is suitable for an earthen or rockfill dam, which at a height of 150 feet will back the water up four miles, filling a beautiful valley and impounding 60000 acre feet. Coyote reservoirs #1 and #2 may be regarded in their storage effect as a single reservoir of 120000 acre feet capacity, since the overflow of #2 will pass into and through #1.

Uvas (Figs. 19, 20, 21 & 22) (Plates 35 & 36)

This site is located in Uvas Canon about eight miles above Gilroy, the damsite being just below Eastman canon at the location of the present diversion dam of the Gilroy Waterworks. The reservoir will impound 20,000 acre feet with a dam 130 feet in height.

Llagas (Figs. 23 & 24) (Plates 37 & 38)

Two excellent reservoir sites are available on Llagas Creek, but owing to limited water supply, only the lower site will be

FIG. 15.

Coyote Upper Gorge Reservoir Site.

FIG. 16

Coyote Upper Gorge Dam Site.

FIG. 17

Coyote - Upper Reservoir Site

FIG. 18

Coyote Upper Dam Site-Left Abutment.

Fig. 19.

Uvas Reservoir Site.

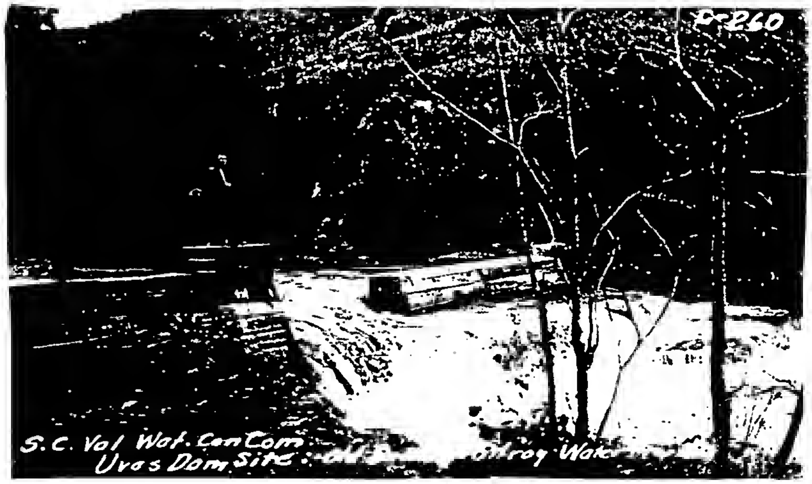


Fig. 20

Uvas Creek at Dam Site Jan. 27, 1921

FIG. 21

FIG. 22

Uvas Dam Site-Left Abutment-
(Morgan Hill in back fround)

Uvas Dam Site-Right Abutment-

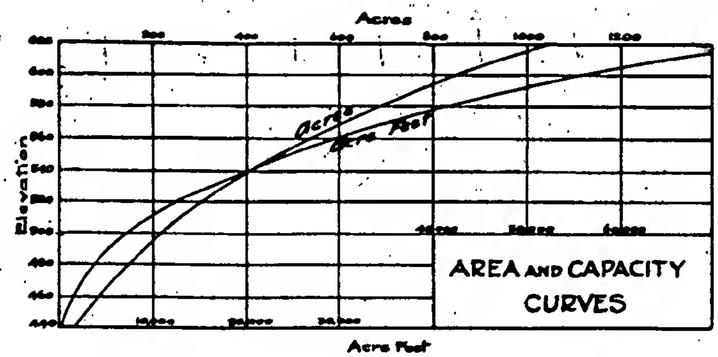
FIG. 23

Llagas Reservoir Site.

FIG. 24. Llagas Dam Site.

FIG. 25 Almaden Reservoir Site.

FIG. 26. Almaden Dam Site.



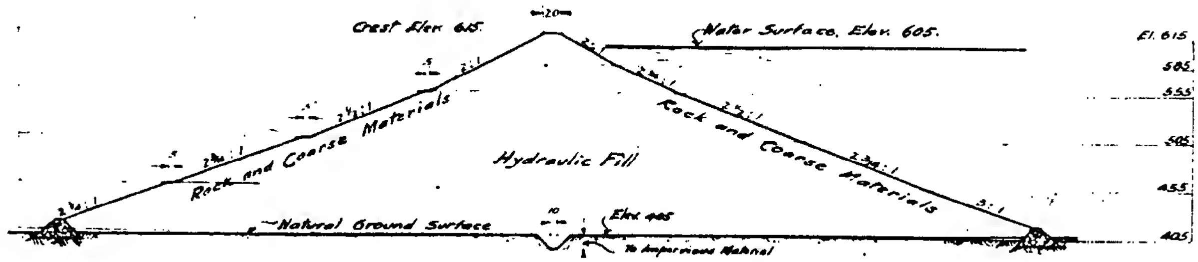
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

COYOTE RESERVOIR No. 1.

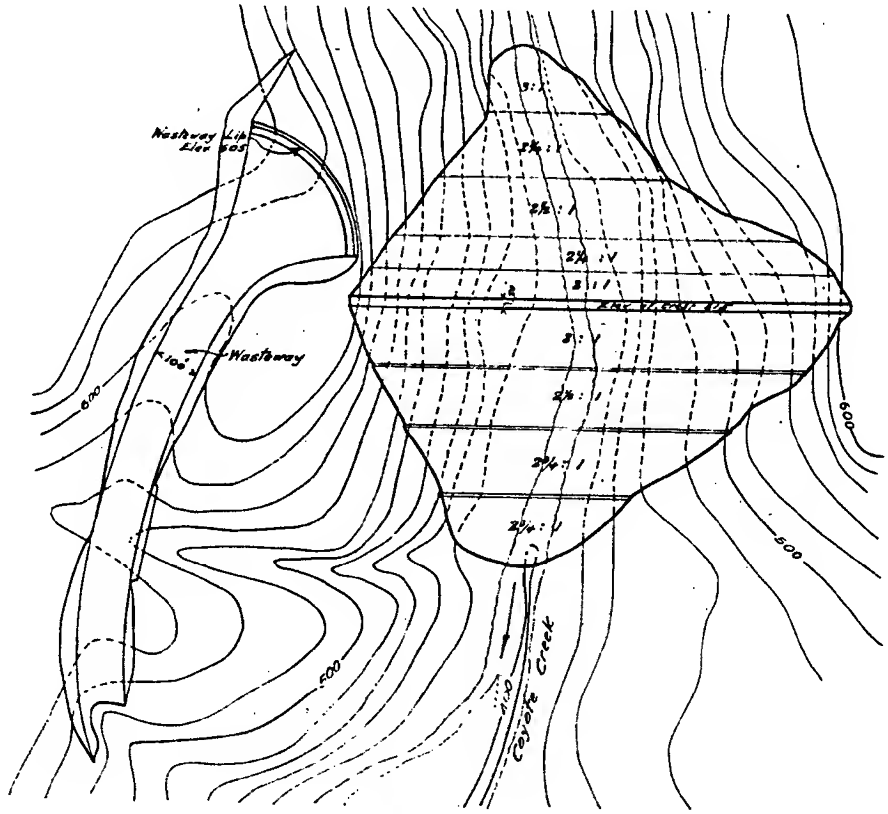
Fred H. Tibbetts, Cons. Engr.   Stephen E. Kieffer, Cons. Engr.

Datum Assumed.   March 1921.

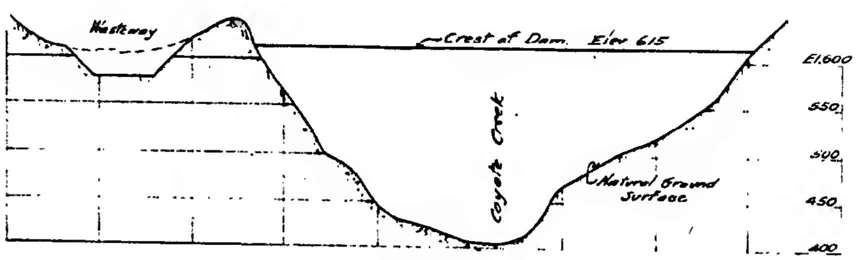
PLATE 31



MAXIMUM SECTION



PLAN



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

COYOTE DAM No. 1.

Fred H. Tibbetts. Cons. Engr.
Stephen E. Kieffer. Cons. Engr.

Datum Assumed.

March 1921.

PLATE 32

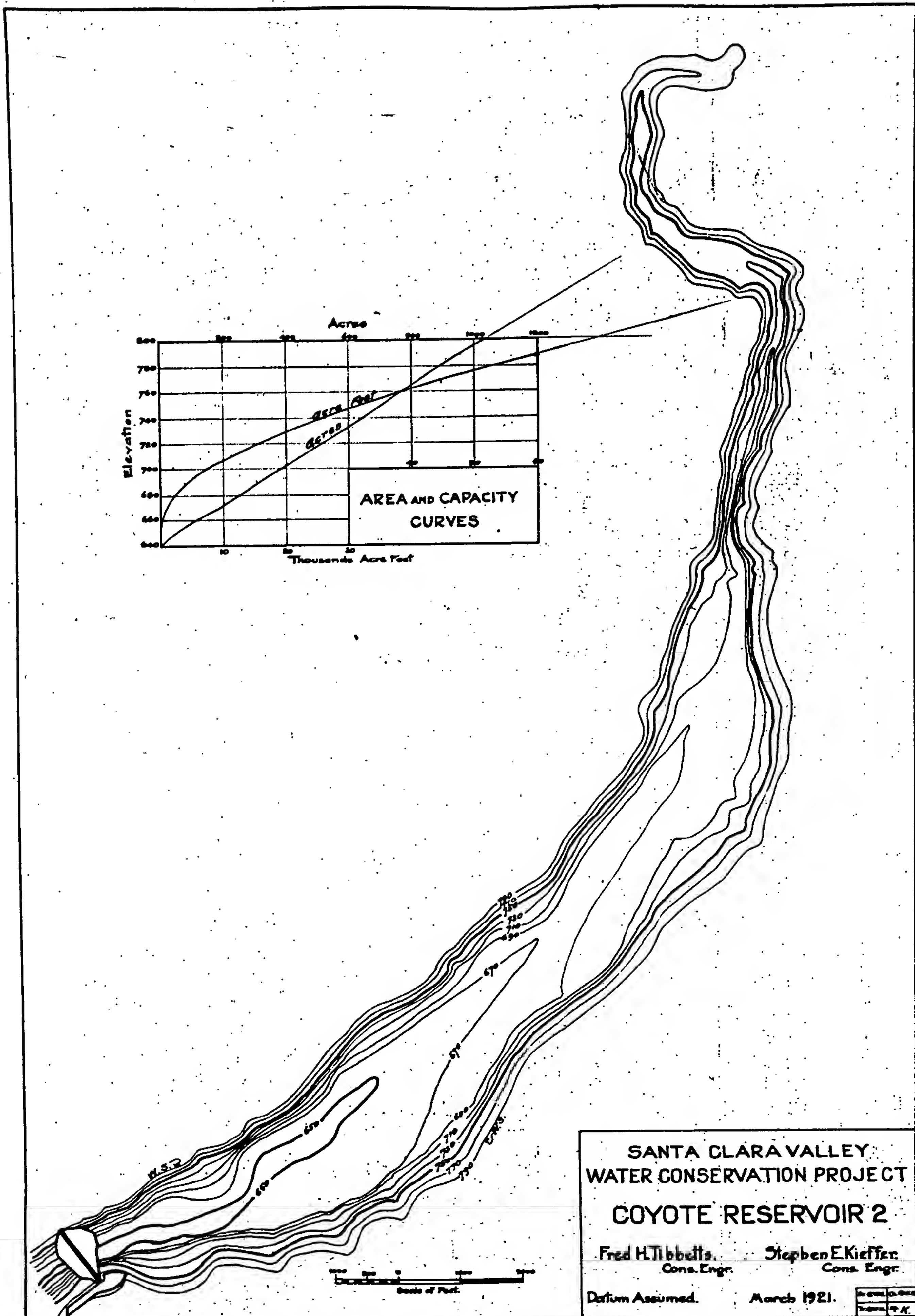
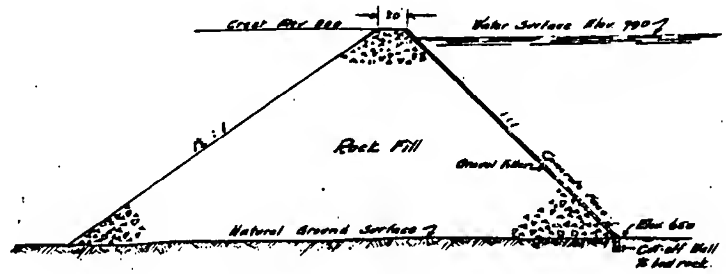
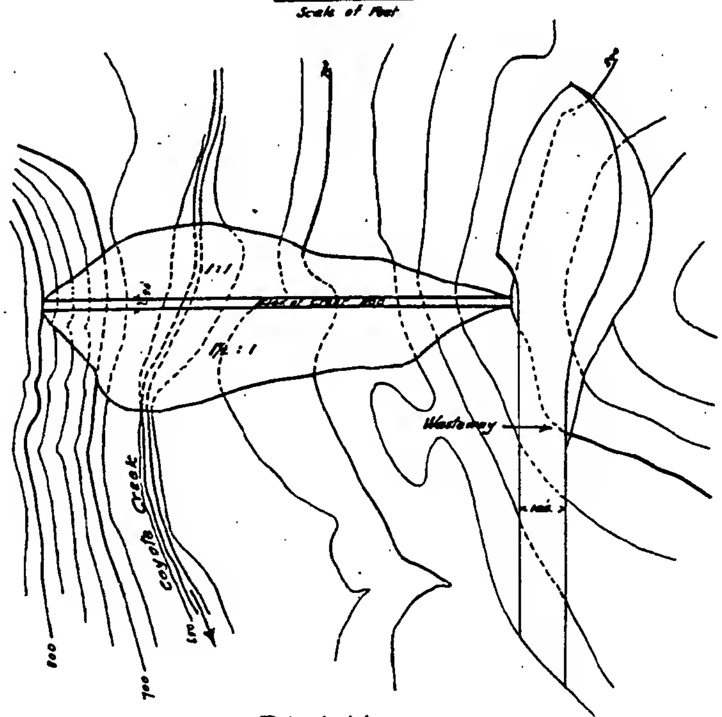

Acres
Elevation
Acre Feet
Acres
AREA AND CAPACITY CURVES
Thousands Acre Feet
W.S.D.
Scale of Feet
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
COYOTE RESERVOIR 2
Fred H. Tibbetts.
Cons. Engr.
Stephen E. Kieffer.
Cons. Engr.
Datum Assumed.
March 1921.

PLATE 33



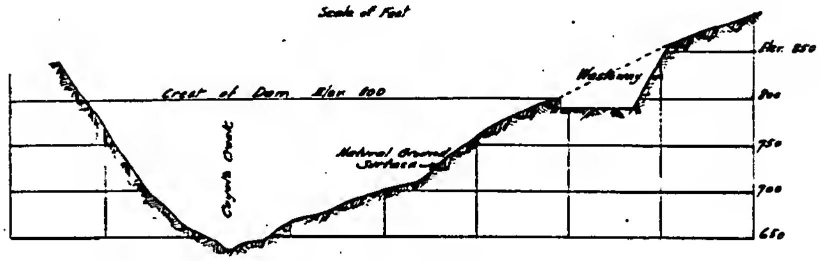
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

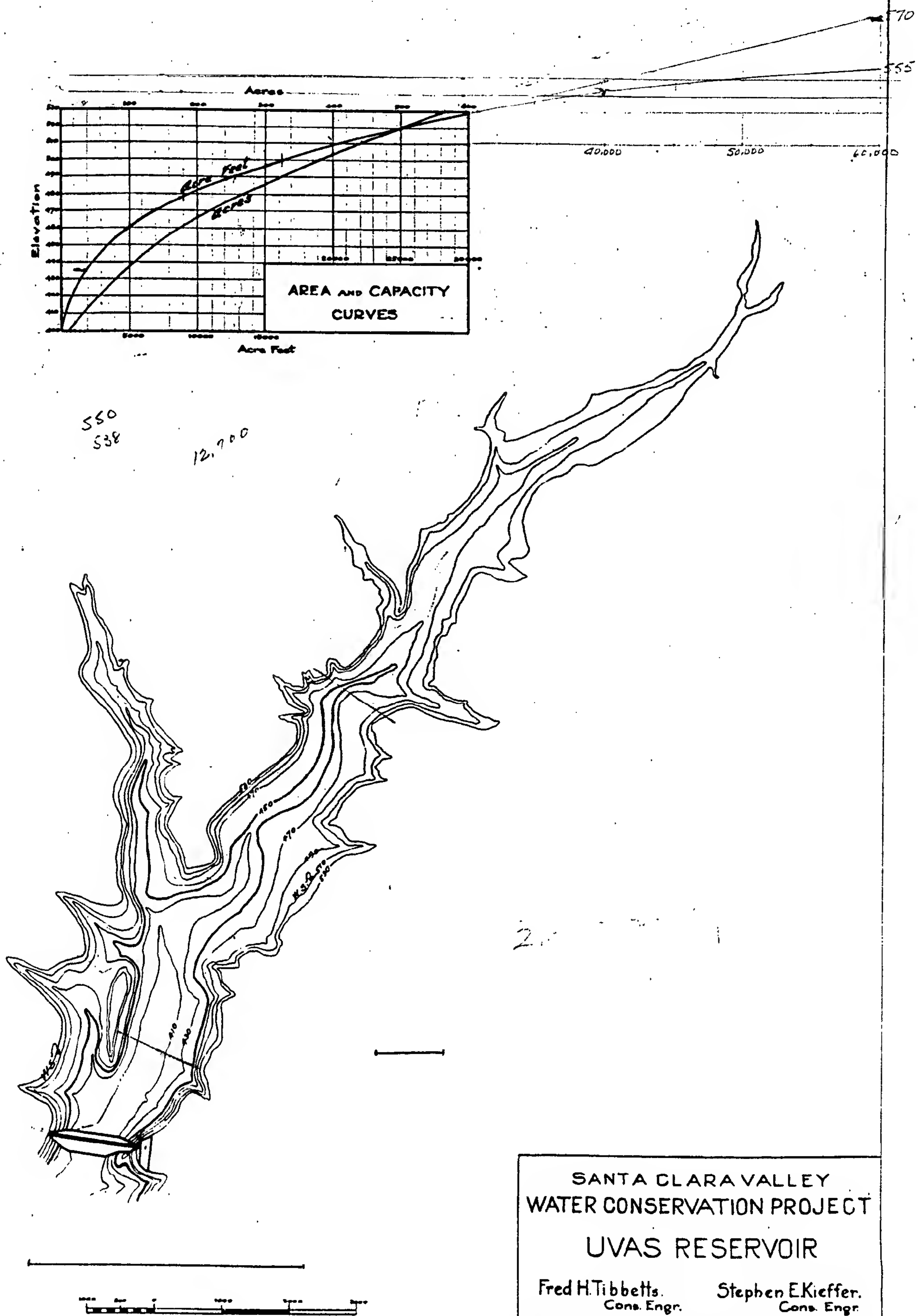
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

COYOTE DAM No. 2

Fred H. Tibbetts. Cons. Engr. — Stephen E. Kieffer. Cons. Engr.

Datum Assumed. — March 1921.

PLATE 34



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

UVAS RESERVOIR

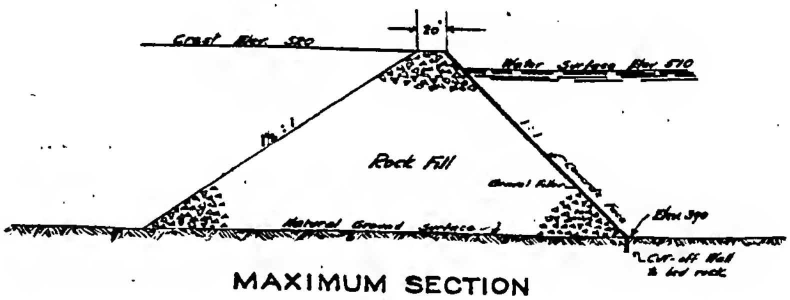
Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

Datum Assumed.

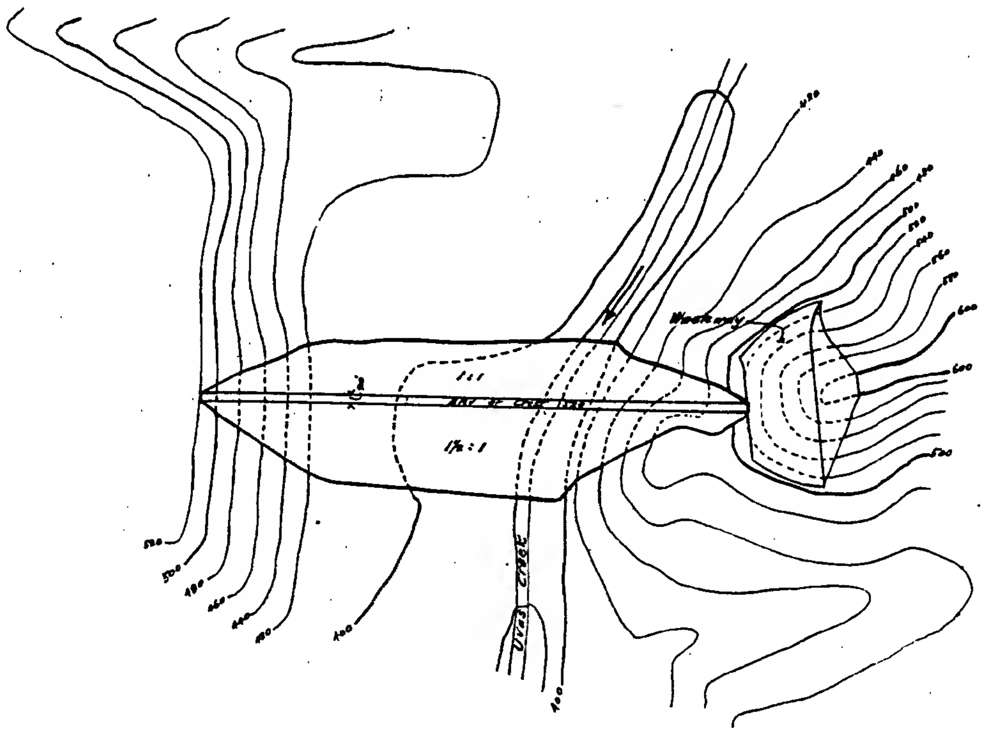
March 1921.

PLATE 35



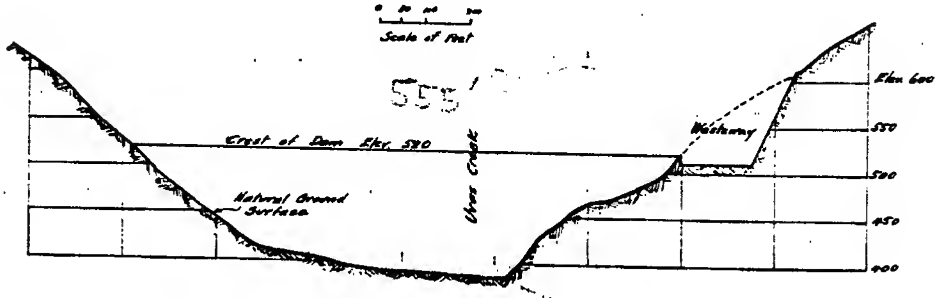
MAXIMUM SECTION

0 50 100
Scale of Feet



PLAN

Scale of Feet



PROFILE

3901

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

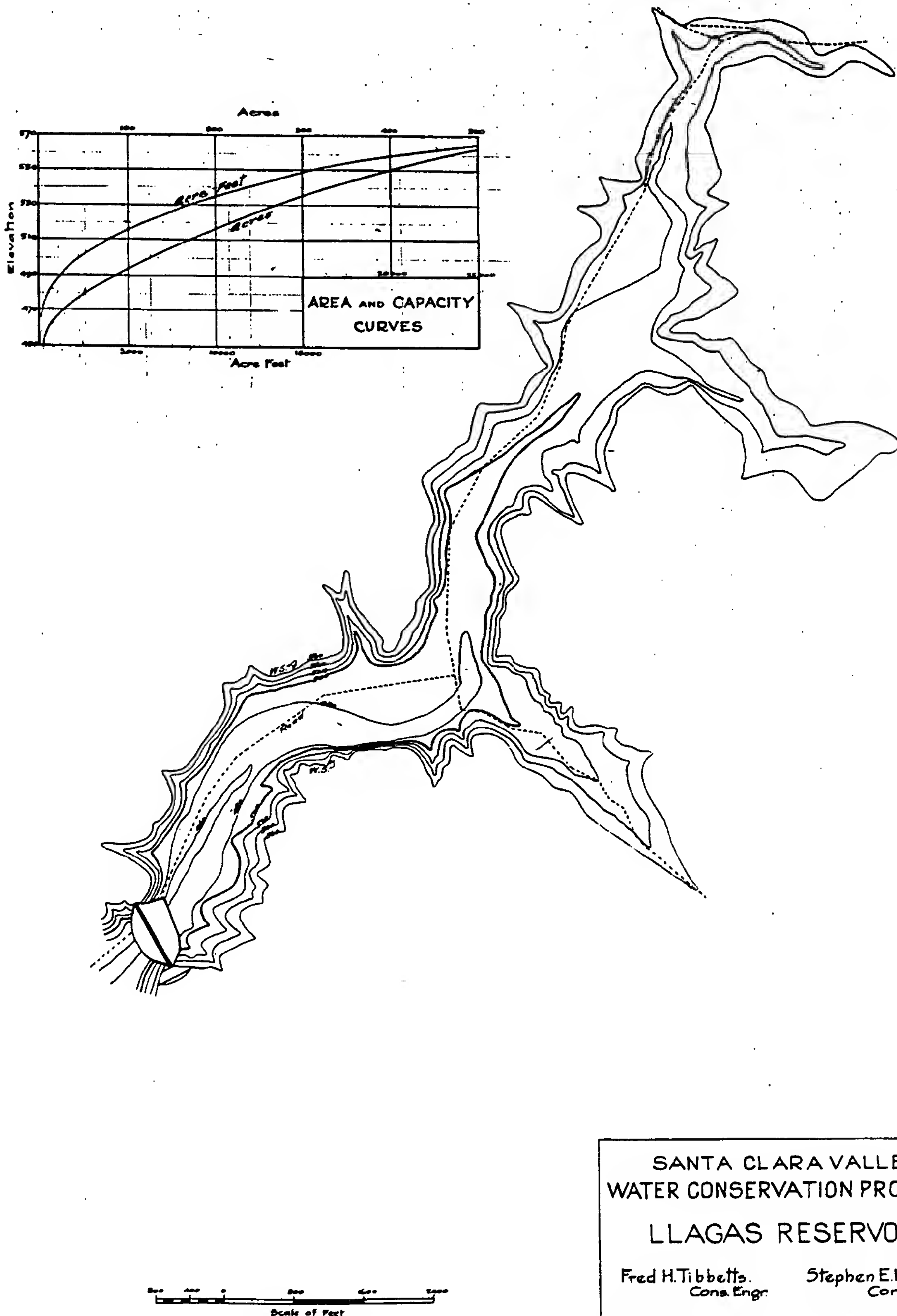
UVAS DAM

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

Datum Assumed.

March 1921.



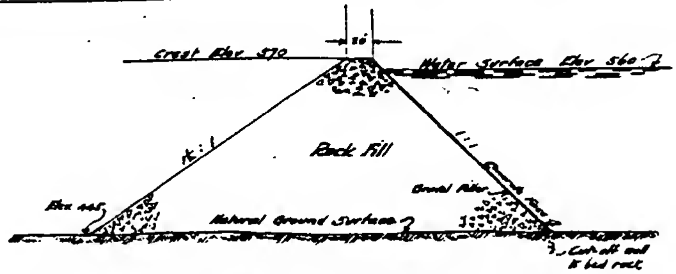
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

LLAGAS RESERVOIR

Fred H. Tibbetts. Cons. Engr.
Stephen E. Kieffer. Cons. Engr.

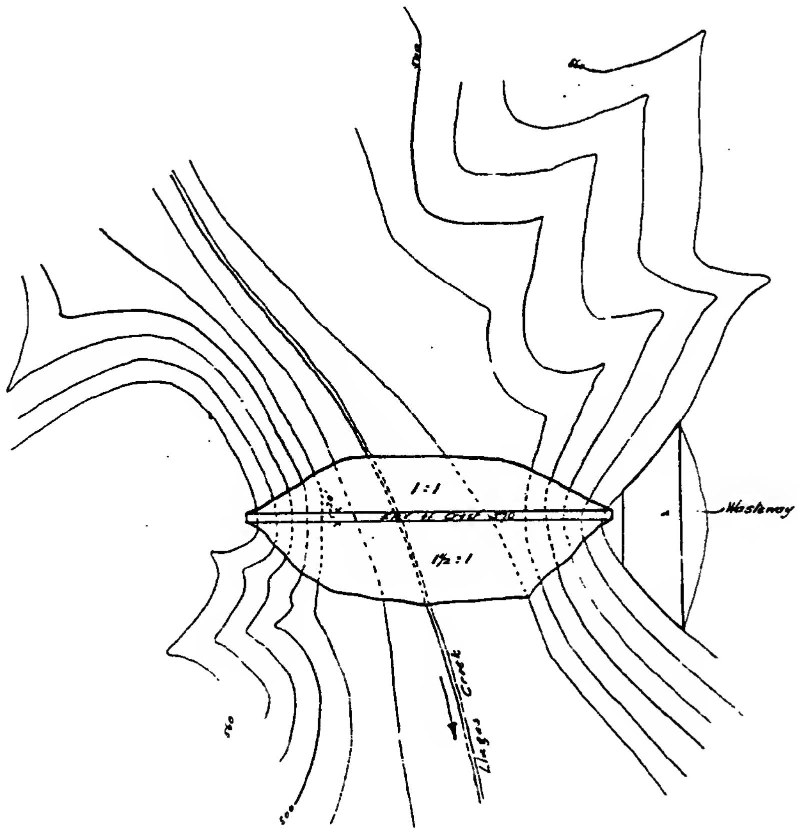
Datum Assumed. March 1921.

PLATE 37



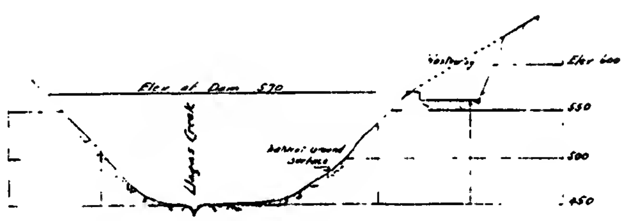
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

LLAGAS DAM

Fred H. Tibbetts. Cons. Engr.

Stephen E. Kieffer. Cons. Engr.

Datum Assumed.

March 1921

PLATE 38

considered. This is located near the upper end of Paradise Valley. A dam 125 feet high will create a reservoir impounding 20,000 acre feet of water.

Calero (Fig. 27) (Plates 39 & 40)

This is located on Calero Creek, a branch of Alamitos Creek, about two and a half miles above the old Almaden R.R. Station. A broad flat valley can be enclosed by a dam 90 feet high to create a reservoir impounding 9,000 acre feet of water. A secondary embankment 30 feet high must be built to close a small gap. This storage will be made fully available by diversion from the Almaden reservoir through a canal and tunnel.

Almaden (Figs. 25 & 26) (Plates 41 & 42)

Located about one mile above the Almaden Mine on Alamitos Creek a masonry dam 110 feet high will create a narrow canon reservoir impounding 2500 acre feet of water. This will serve as a check reservoir for flood peaks to permit of their transmission and storage in Calero reservoir, both reservoirs being treated as one in their operation.

Guadalupe #1 & #2 (Figs. 28 & 29) (Plates 43 to 46)

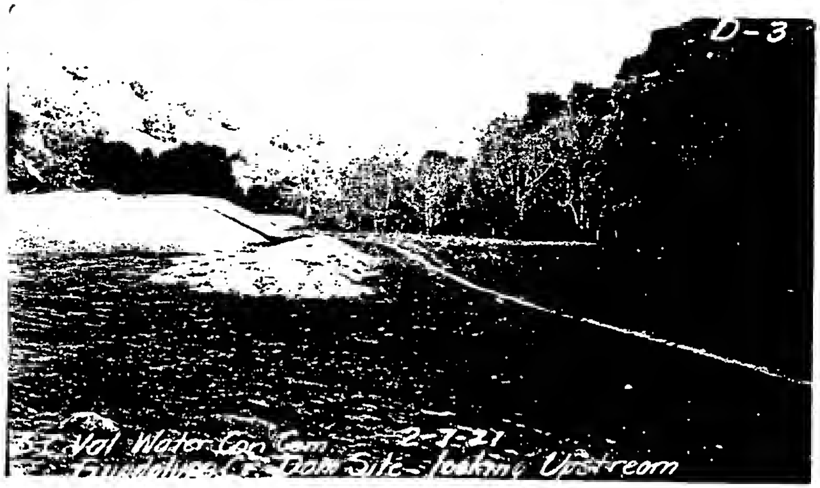
Reservoir #1 is located about 1-3/4 miles above the Guadalupe Mine on Guadalupe Creek. A dam 105 feet high will create a reservoir of 2300 acre feet capacity and back the water up one mile to Reservoir #2, where a dam 90 feet high will create a second reservoir with 1200 acre feet capacity. A dam 125 feet high at Reservoir #1 will impound 3500 acre feet of water at less cost than the same storage in the two separate reservoirs.

Calero Creek Dam Site.

FIG. 27.

Guadalupe Creek Reservoir Site.

FIG. 28.



Guadalupe Creek Dam Site.

FIG. 29.

Azule Springs Reservoir Site.

FIG. 30.

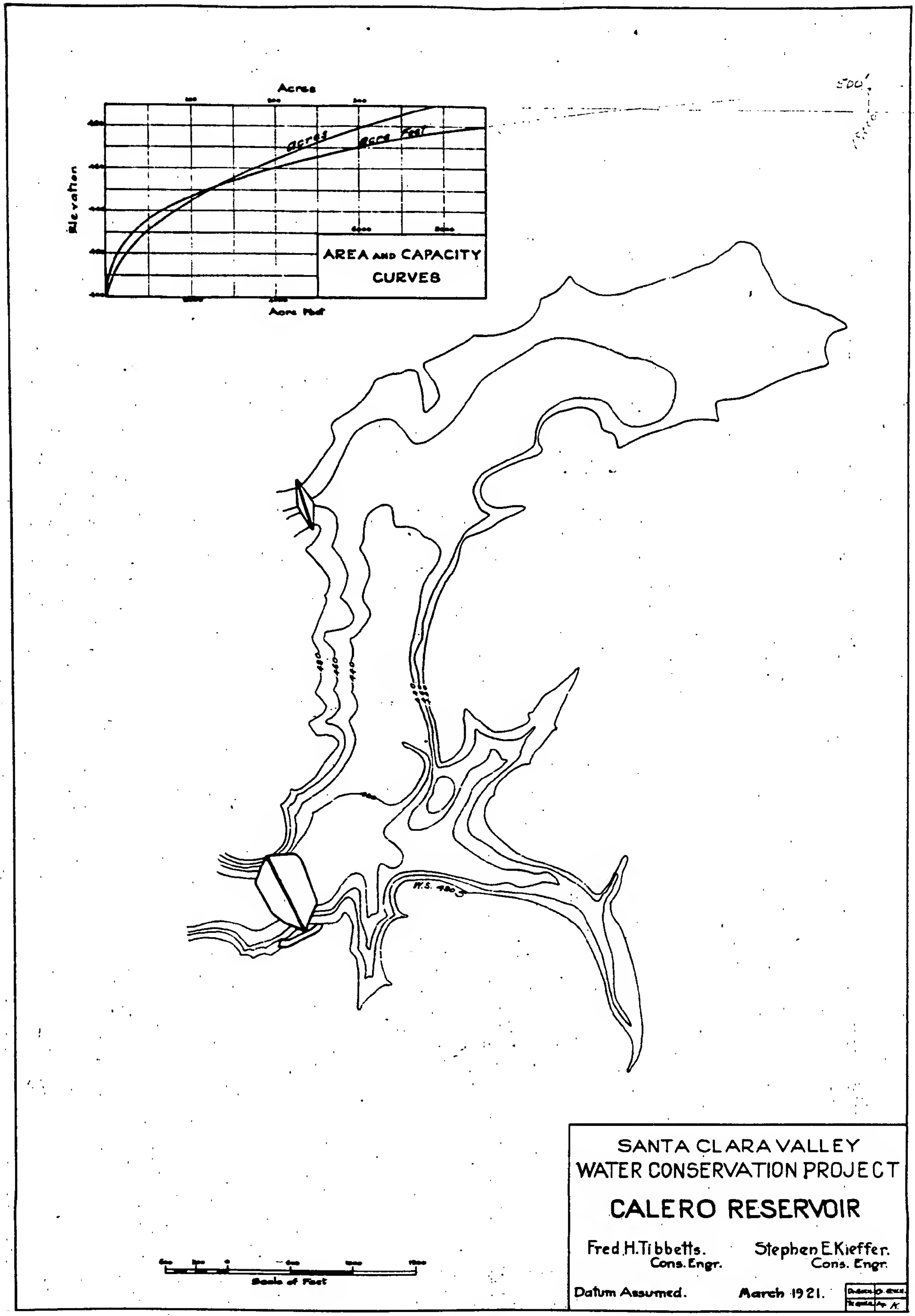
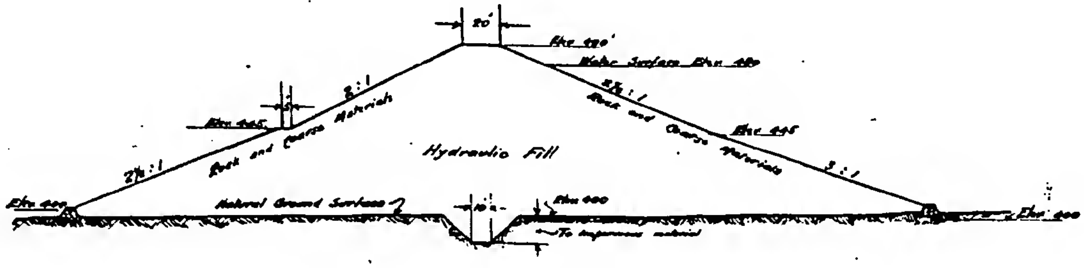
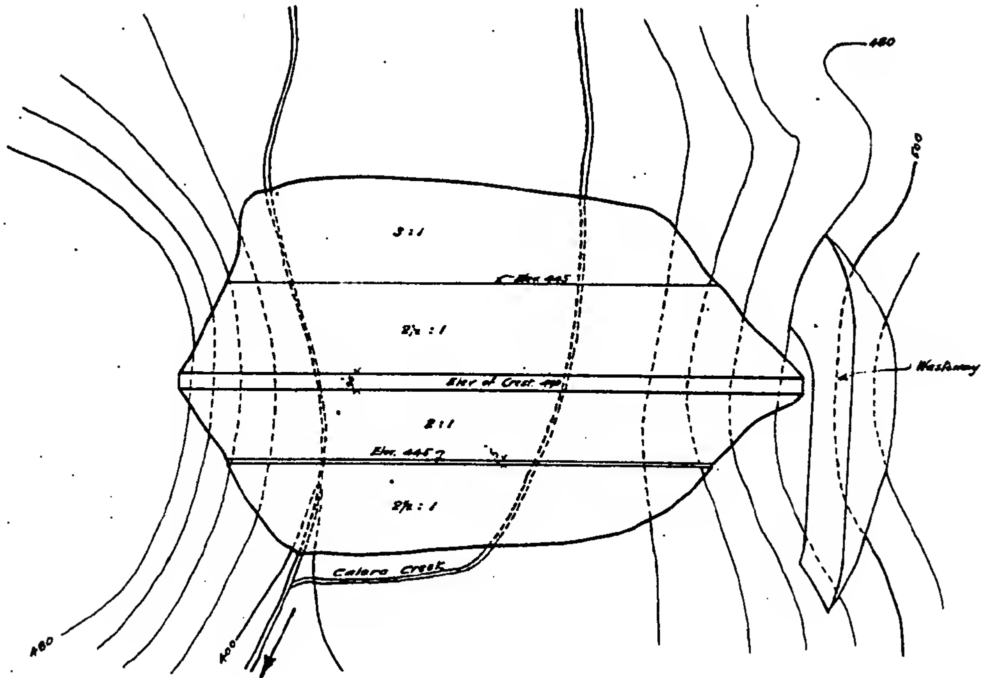

Acres
Elevation
Acre Feet
AREA AND CAPACITY CURVES
Acres
Acre Feet
480
W.S. 480
Scale of Feet
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
CALERO RESERVOIR
Fred H. Tibbetts. Cons. Engr.
Stephen E. Kieffer. Cons. Engr.
Datum Assumed.
March 1921.

PLATE 39



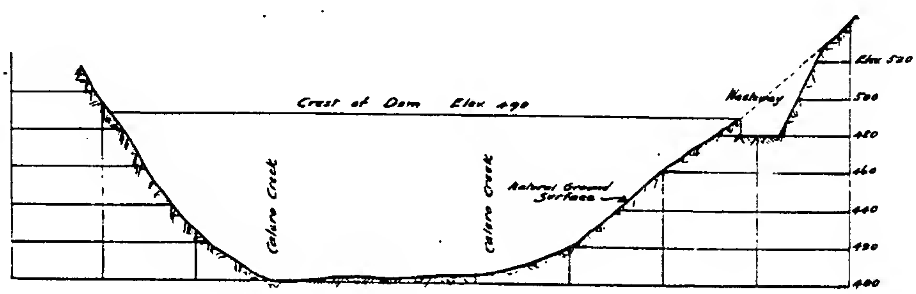
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

CALERO DAM

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

Datum Assumed.

March 1921.

PLATE 40

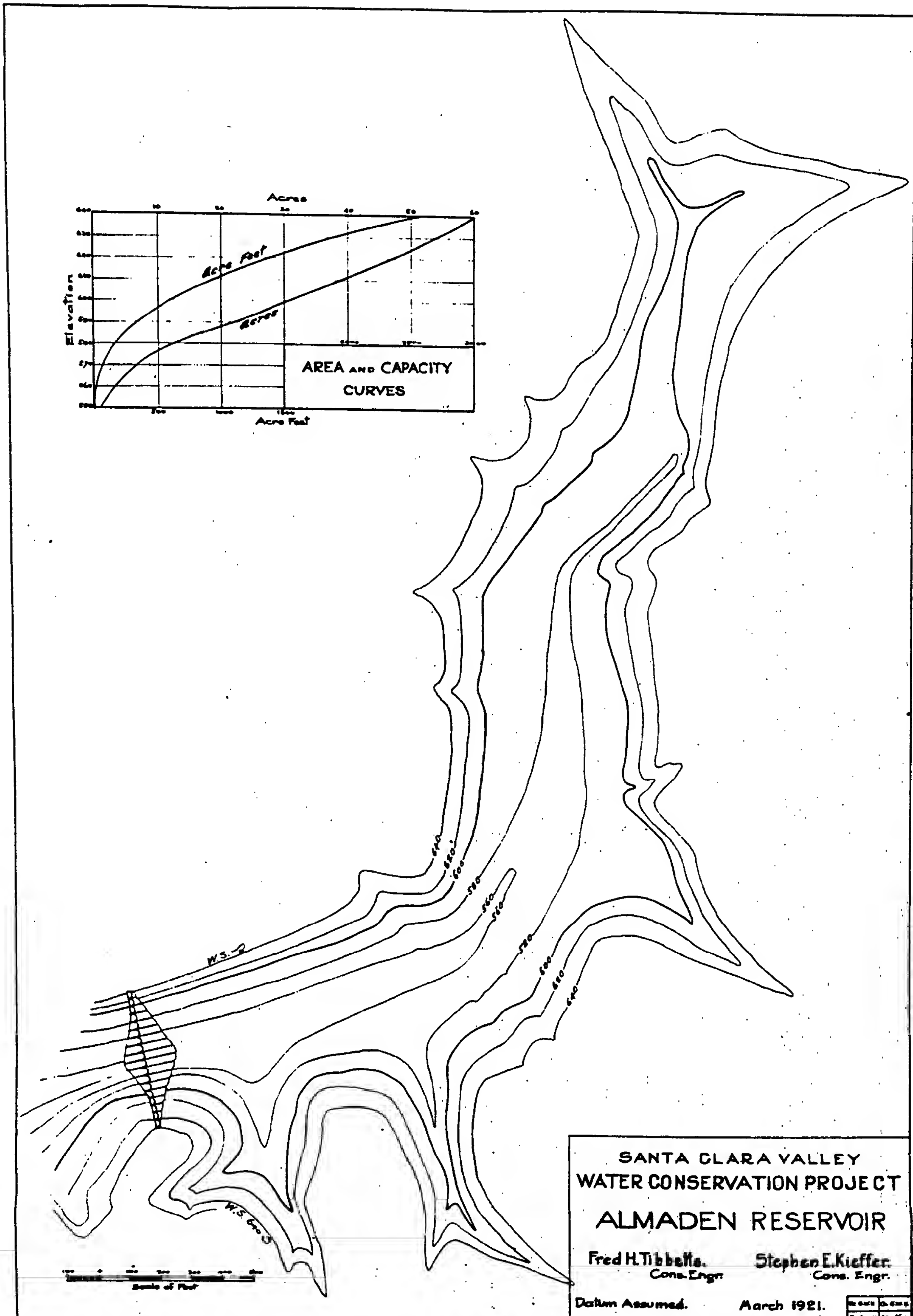
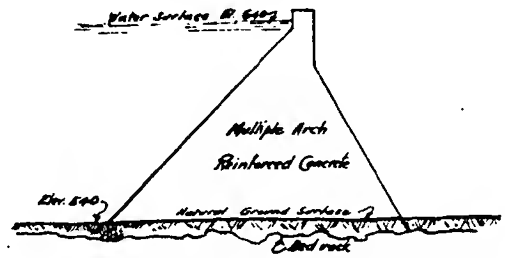
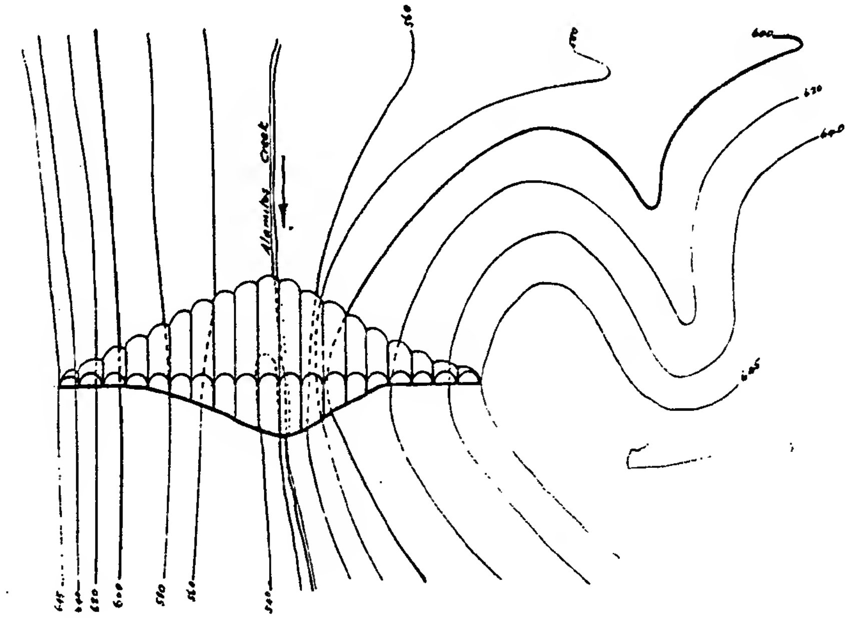

Acres
Elevation
Acre Feet
Acres
AREA AND CAPACITY CURVES
Acre Feet
640
620
600
580
560
Scale of Feet
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
ALMADEN RESERVOIR
Fred H. Tibbetts.
Cons. Engr.
Stephen E. Kieffer.
Cons. Engr.
Datum Assumed.
March 1921.

PLATE 41



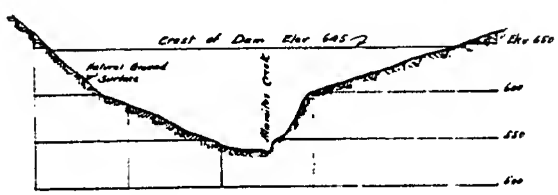
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

ALMADEN DAM

Fred H. Tibbetts.
Cons Engr.

Stephen E. Kieffer.
Cons Engr.

Datum Assumed.

March 1921.

PLATE 42

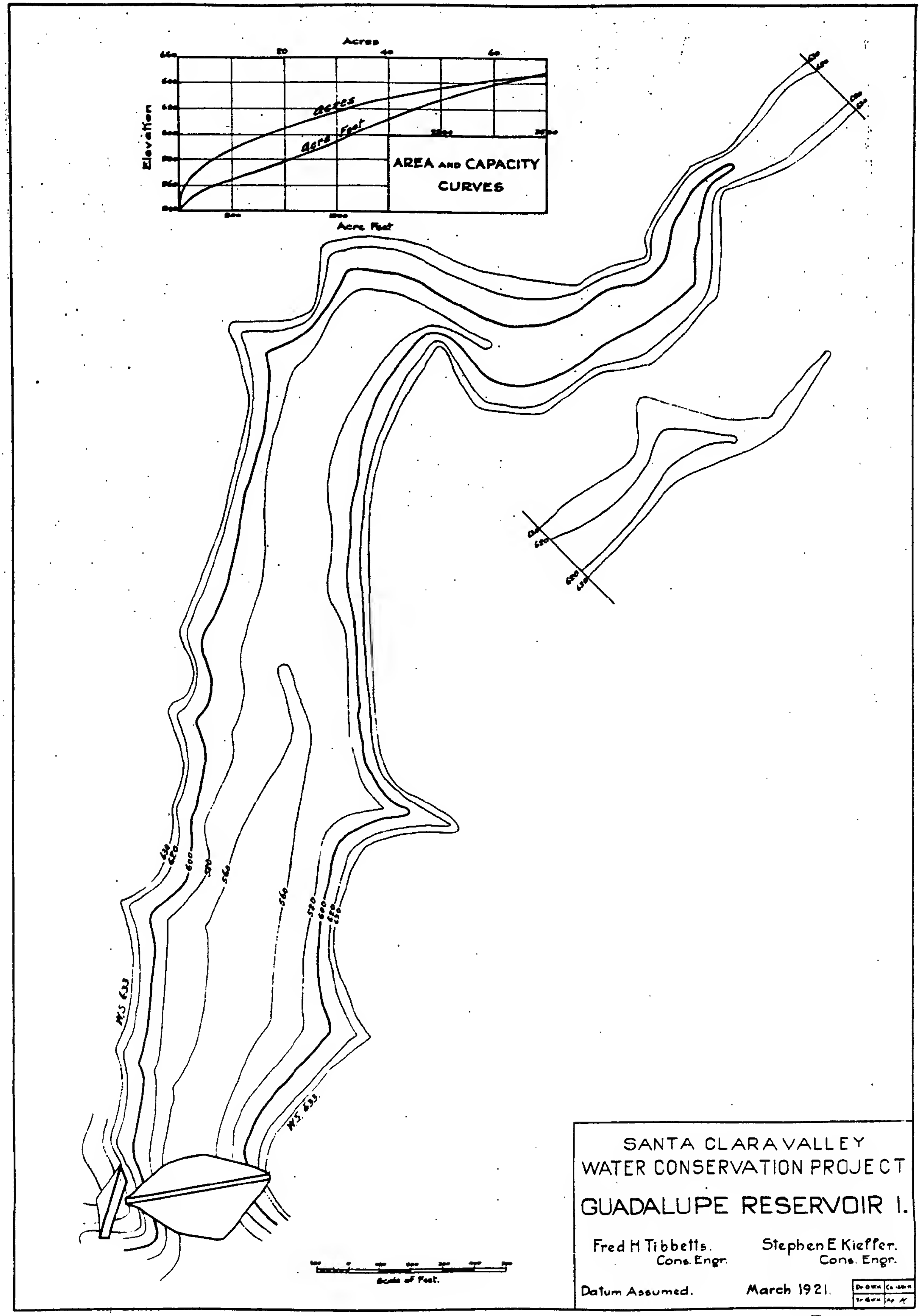
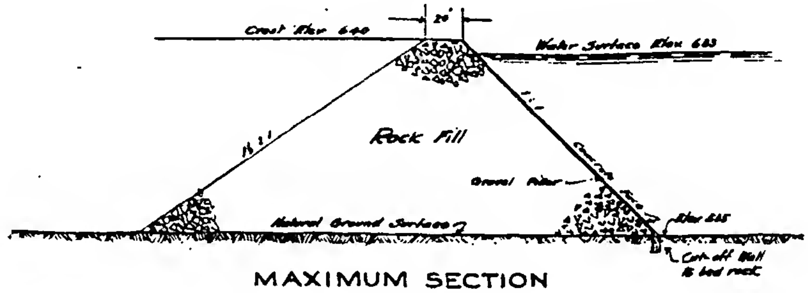
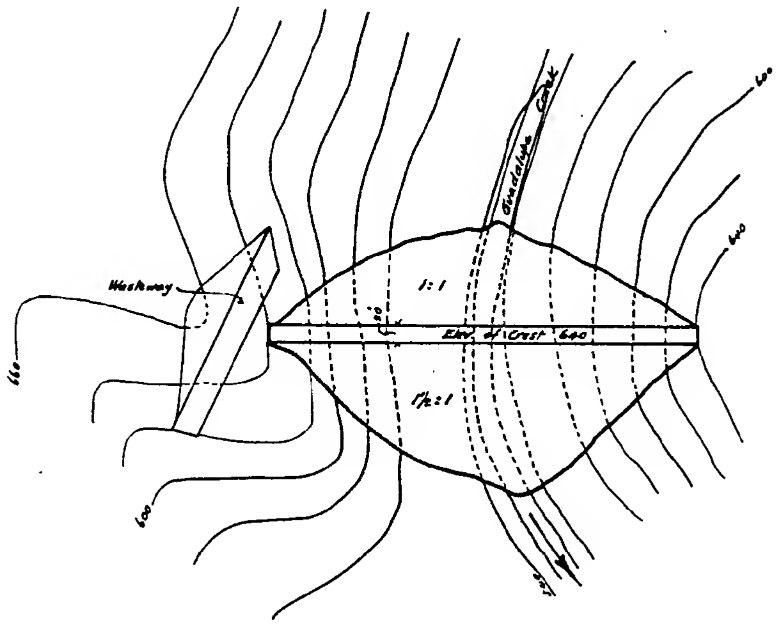

Acres
20
40
60
Elevation
Acres
Acre Feet
AREA AND CAPACITY CURVES
Acre Feet
630
620
600
580
560
W.S. 633
Scale of Feet
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
GUADALUPE RESERVOIR I.
Fred H Tibbetts.
Cons. Engr.
Stephen E Kieffer.
Cons. Engr.
Datum Assumed.
March 1921.

PLATE 43



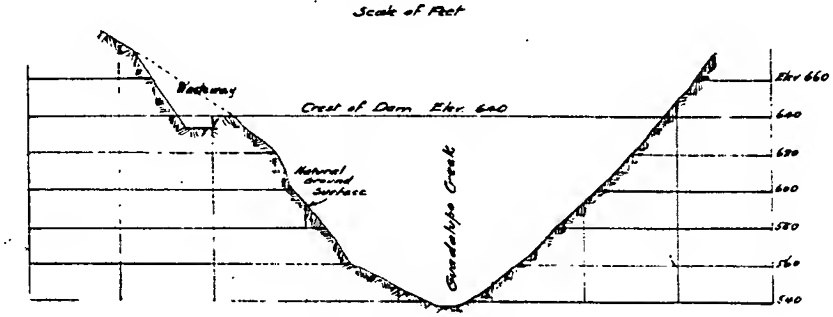
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



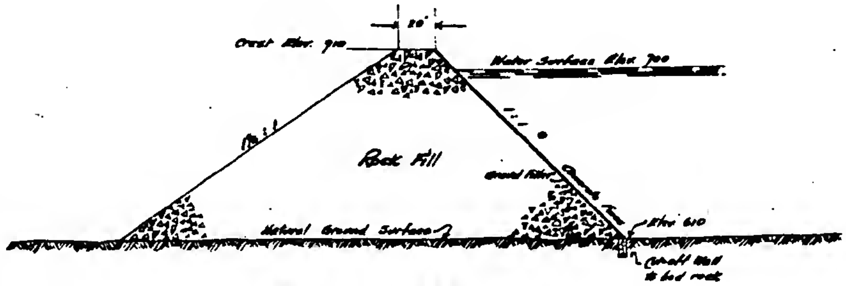
PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

GUADALUPE DAM No. 1

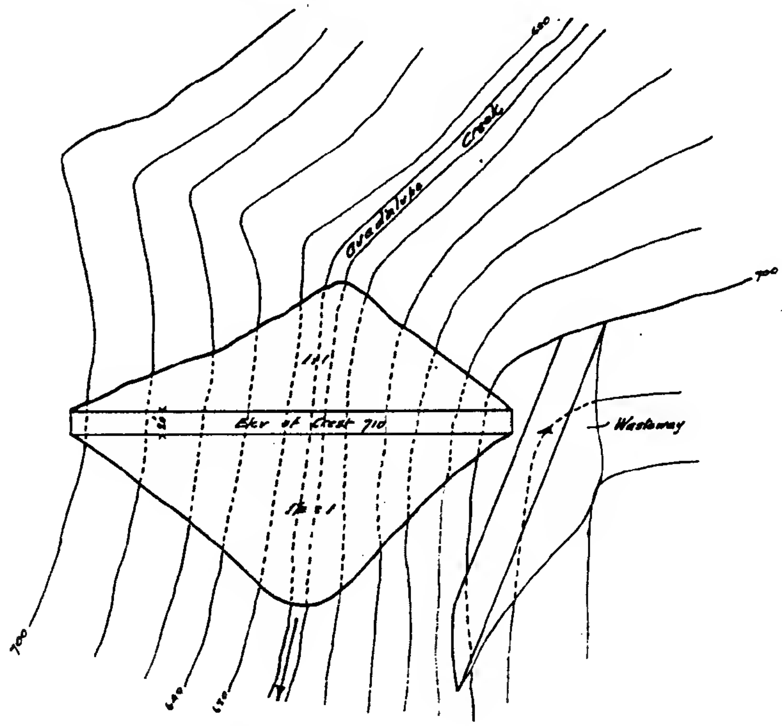
Fred H. Tibbetts. Cons. Engr. | Stephen E. Kieffer. Cons. Engr.

Datum Assumed. March 1921.



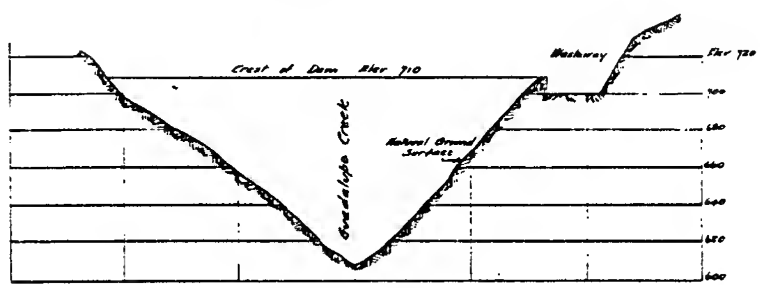
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

GUADALUPE DAM No. 2

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

Datum Assumed.

March 1921.

PLATE 46

Guadalupe #3 (Plates 47 &48)

The damsite for this reservoir is located near the mouth of the Guadalupe canon, where a dam 83 feet high will impound 3,000 acre feet of water, extending up the canon to the Guadalupe Mine.

The great length and height of this dam for the limited amount of storage and the valuable property submerged will probably prove to be the objectinnable features of this reservoir.

Calabazas (Azule Springs) (Fig. 30) (Plates 49 &50)

This site is located on the South fork of Calabazas Creek just below Azule Springs. A dam 108 feet high will impound 1600 acre feet of water. The runoff from Calabazas Creek is insufficient to fill this reservoir on most years, and it will be supplied by a conduit diverting from Stevens Creek.

Stevens Creek

No. 1. (Figs. 31 & 32) (Plates 51 & 52) The damsite for this reservoir is located on Stevens Creek one mile above the mouth of the canon. A dam 107 feet high will create a reservoir two miles in length and impound 4,000 acre feet of water.

No. 2. (Figs. 33 & 34) (Plates 53 & 54) This is located on the upper reaches of Stevens Creek one half mile above Soda Rock. A narrow rocky gorge will permit the construction of a masonry dam, 125 feet high, creating a reservoir with capacity of 2,000 acre feet. From this reservoir the conduit will lead to Calabazas Reservoir.

FIG. 31.

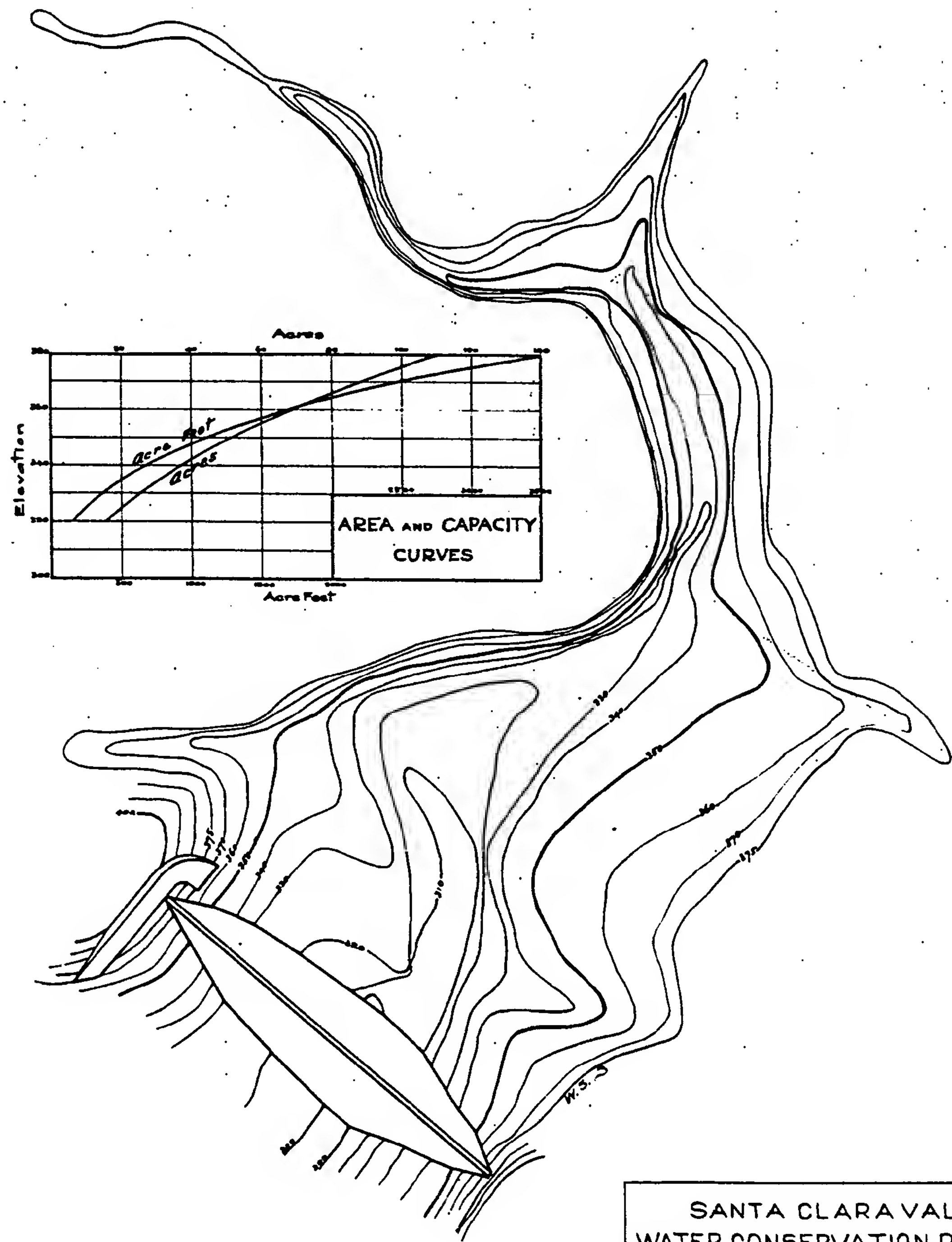
Lower Stevens Creek Reservoir Site.

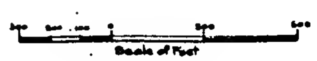
FIG. 32.

Lower Stevens Creek Dam Site.

FIG. 33. Upper Stevens Creek Reservoir Site.

FIG. 34. Stevens Creek Runoff between Dam Sites Feb. 8, 1921.





SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

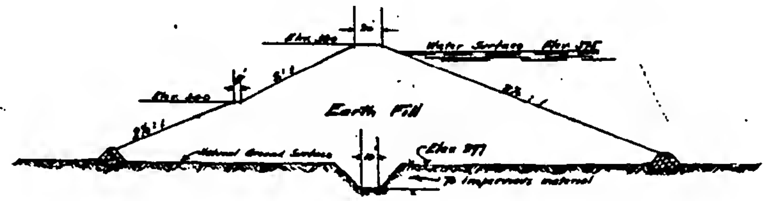
GUADALUPE RESERVOIR 3.

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

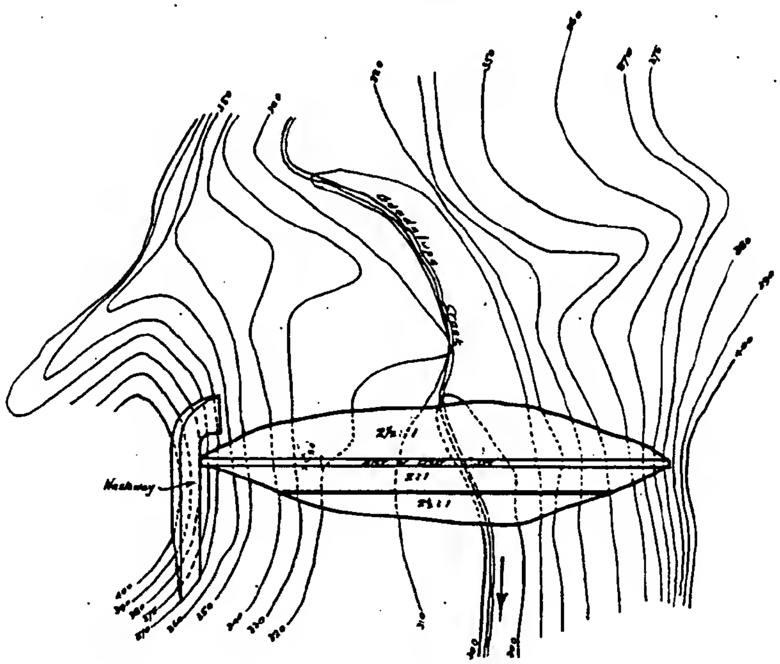
Datum Assumed. March 1921.

PLATE 47



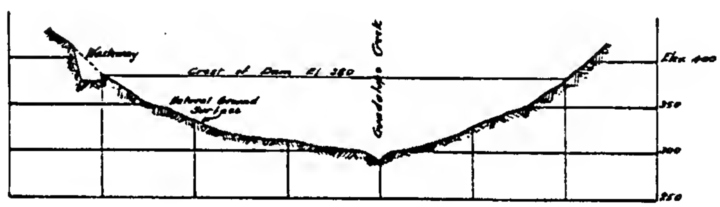
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

GUADALUPE DAM No. 3

Fred H. Tibbetts, Cons. Engr.
Stephen E. Kieffer, Cons. Engr.

Datum Assumed

March 1921

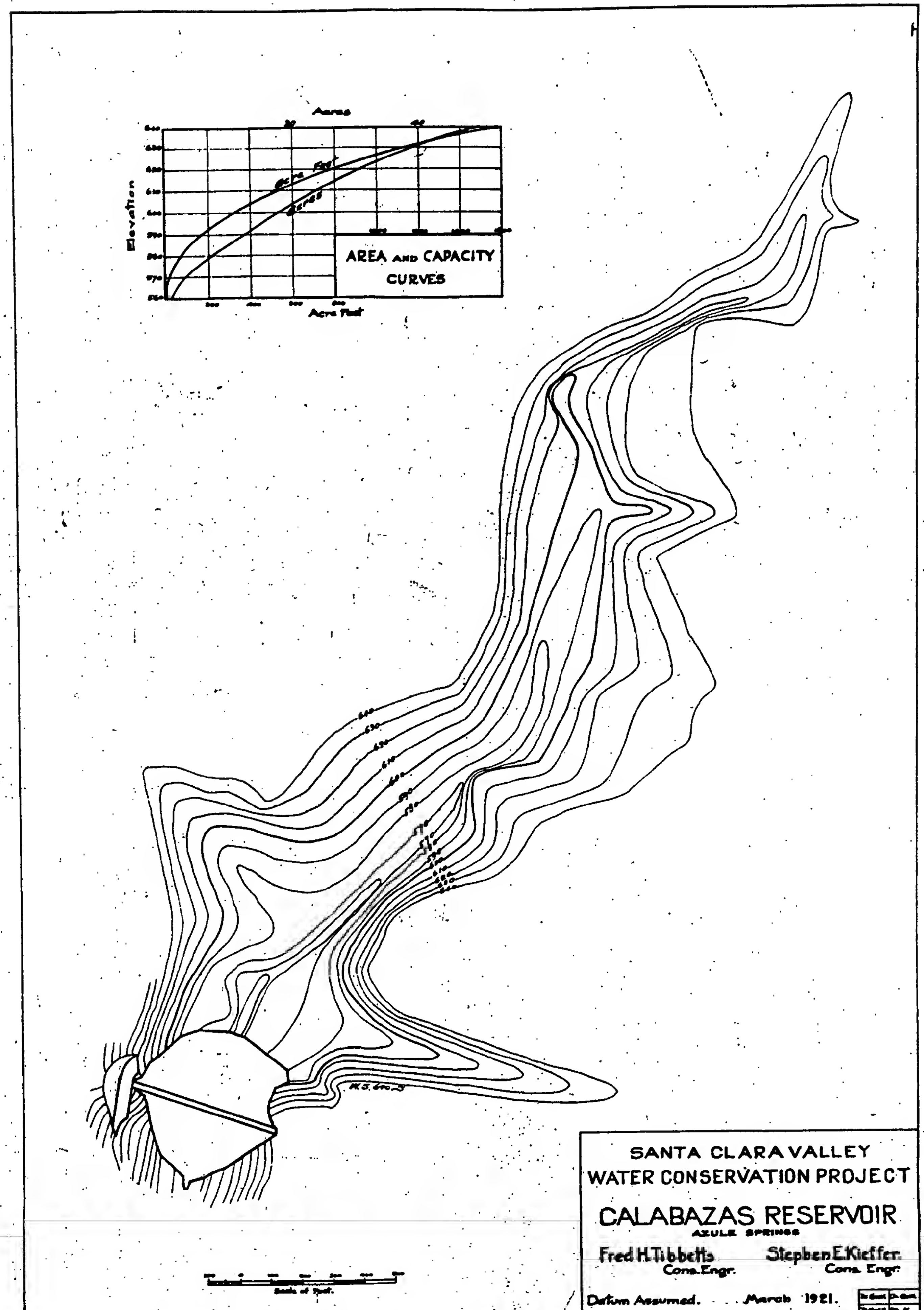
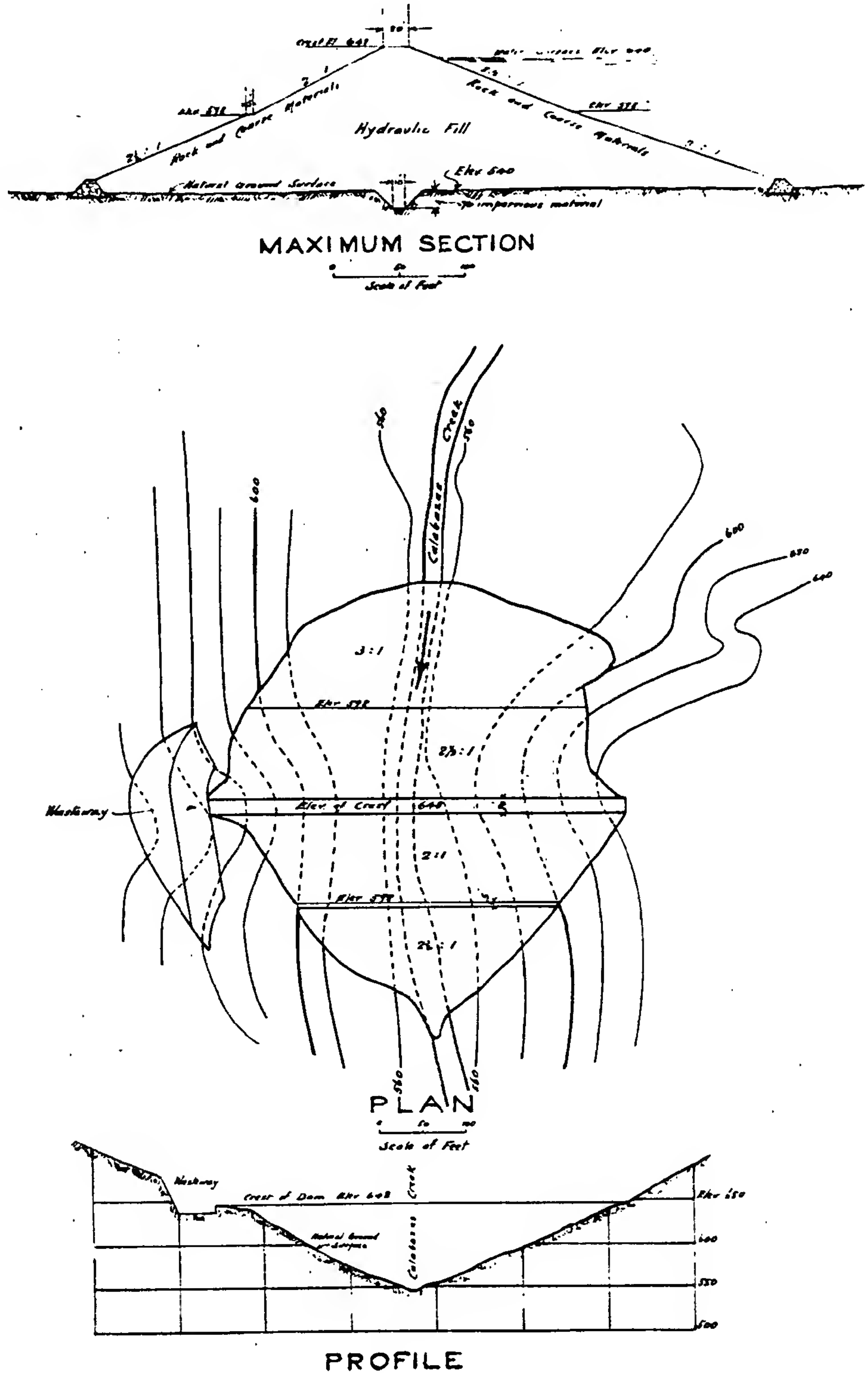

Acres
Elevation
Acre Feet
AREA AND CAPACITY CURVES
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
CALABAZAS RESERVOIR
AZULE SPRINGS
Fred H. Tibbetts
Cons. Engr.
Stephen E. Kieffer.
Cons. Engr.
Datum Assumed. March 1921.
Scale of Feet.

PLATE 49



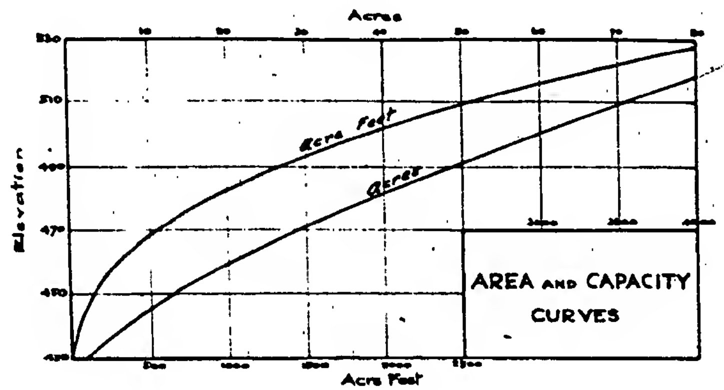
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

CALABAZAS DAM

Fred H. Tibbetts, Cons. Engr.   Stephen E. Kieffer, Cons. Engr.

Datum Assumed.   March 1921.

PLATE 50



Scale of Feet

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

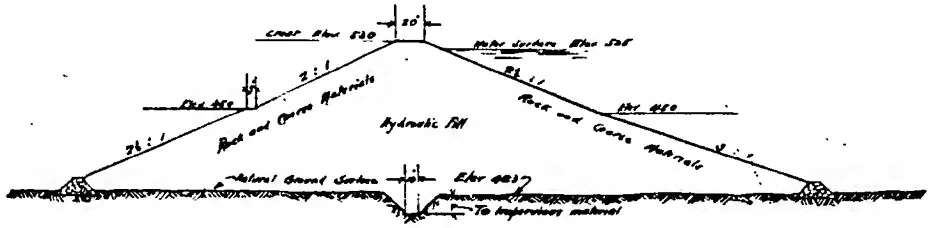
STEVENS CREEK RESERVOIR I

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

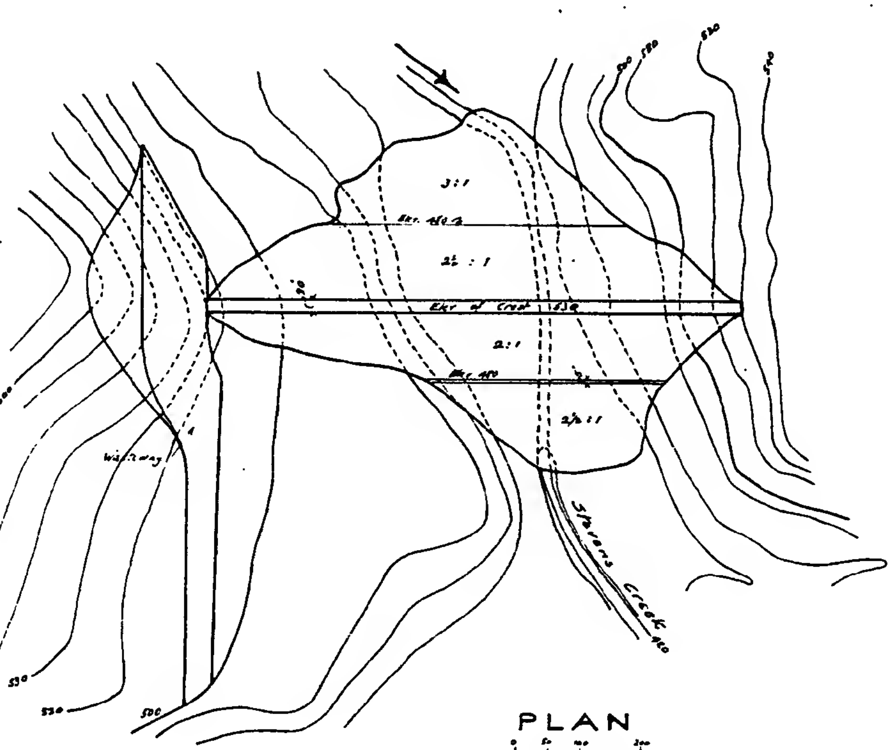
Datum Assumed.

March 1921.



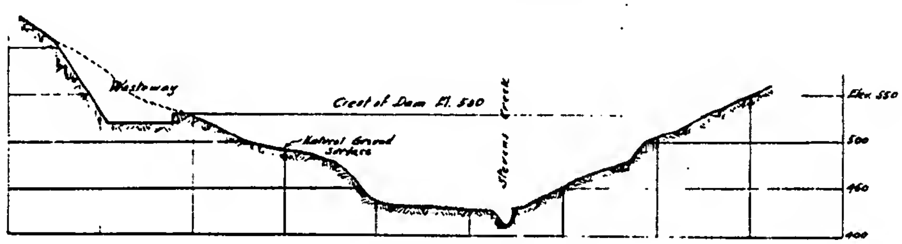
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



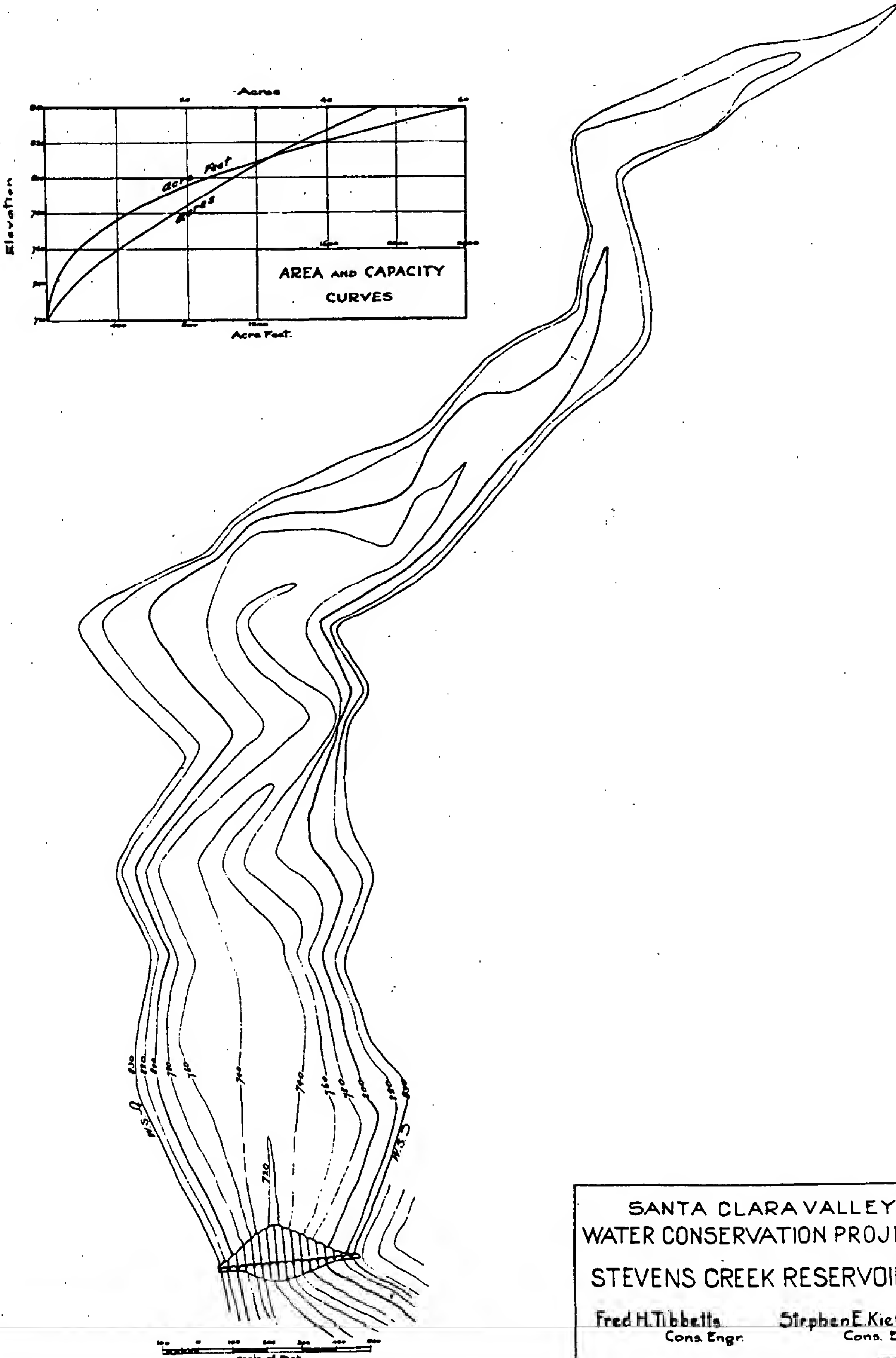
PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

STEVENS CREEK DAM No. 1

Fred H. Tibbetts. Cons. Engr. — Stephen E. Kieffer. Cons. Engr.

Datum Assumed. — March 1921.



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

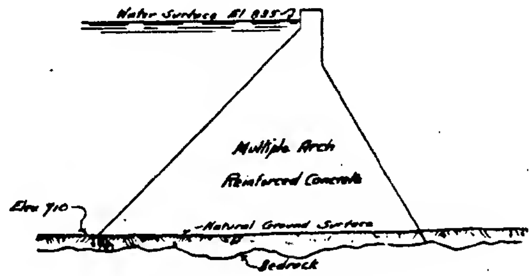
STEVENS CREEK RESERVOIR 2

Fred H. Tibbetts
Cons. Engr.

Stephen E. Kieffer
Cons. Engr.

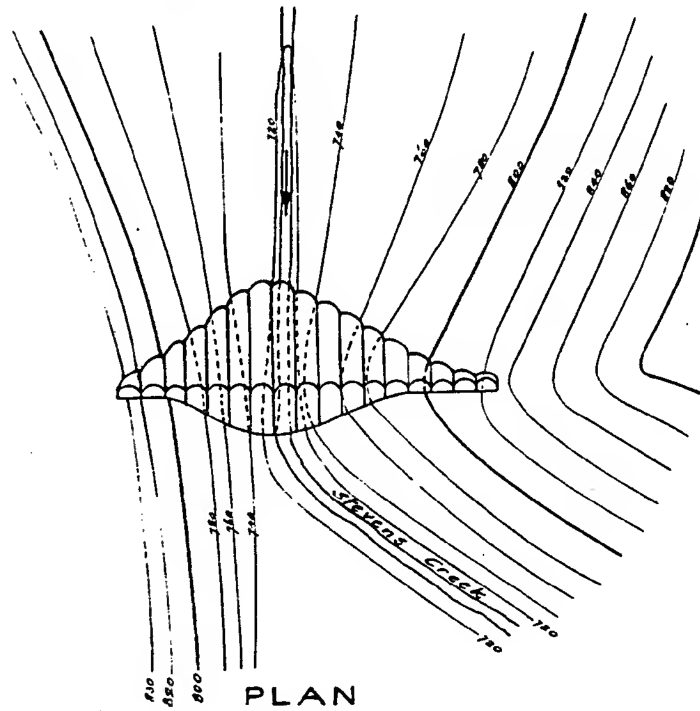
Datum Assumed. March 1921.

PLATE 53



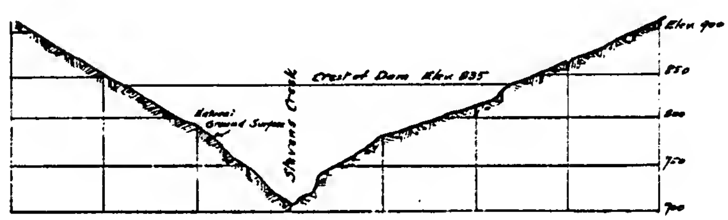
MAXIMUM SECTION

0 50 100
Scale of Feet



PLAN

0 50 100
Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

STEVENS CREEK DAM No. 2

Fred H. Tibbetts. Cons. Engr.

Stephen E. Kieffer. Cons. Engr.

Datum Assumed.

March 1921

<u>No.3.</u> (Plates 55 & 56)

This damsite is located at the canon, one mile below #1, where a dam 65 feet high will create a reservoir with capacity of 600 acre feet and back the water to the toe of Dam #1.

<u>Permanente</u> (Plates 57 to 60)

One reservoir each is located on the South and North Forks near the mouths of the canons. In each case a dam 85 feet high will impound 1100 acre feet of water.

<u>San Antonio</u> (Figs. 35 & 36) (Plates 61 & 62)

This site is located at the junction of the main forks of the San Antonio about four miles above the Griffin Ranch at the edge of the valley. A dam 55 feet high will impound 1000 acre feet of water.

<u>Madera</u> (Figs. 37 & 38) (Plates 63 & 64)

This site is located on the North Fork of Madera Creek four miles from the State Highway. A dam 105 feet high will create a reservoir with a capacity of 5300 acre feet. This will provide storage for all the water of the North Fork of Madera Creek and by diversion the flood flow of Los Trancos Creek.

<u>SEDIMENTATION</u>

Silting, or filling of the reservoirs with solids carried in suspension in the water during flood flow, is a factor to be considered in the ultimate reservoir capacity of any storage project. This is of varying importance dependent upon the size of the reservoir and the

San Antonio Creek Reservoir Site.

FIG. 35.

San Antonio Dam Site.

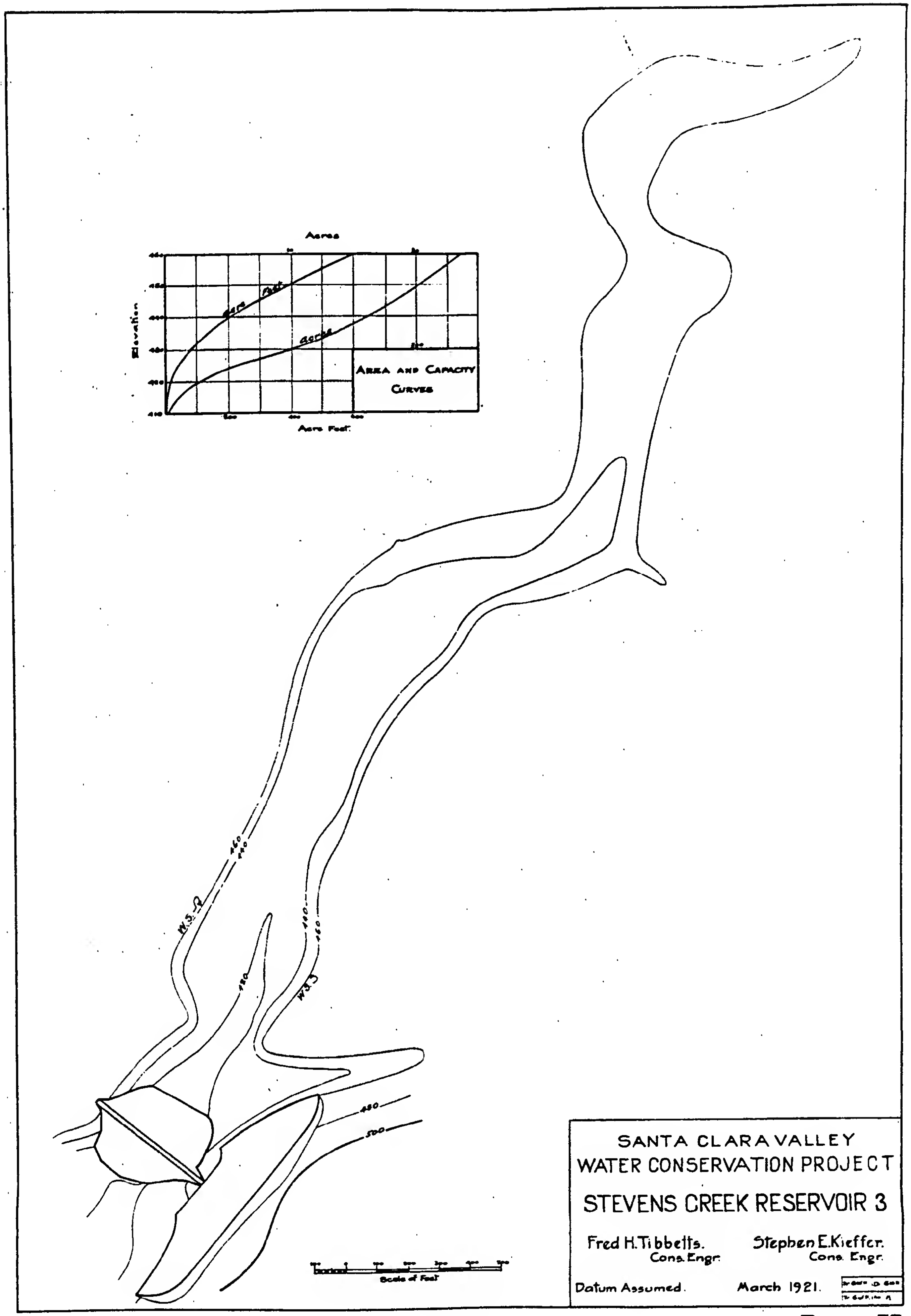
FIG. 36

Madero Creek Reservoir Site.

FIG. 37.

Madero Creek Dam Site.

FIG. 38.



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

STEVENS CREEK RESERVOIR 3

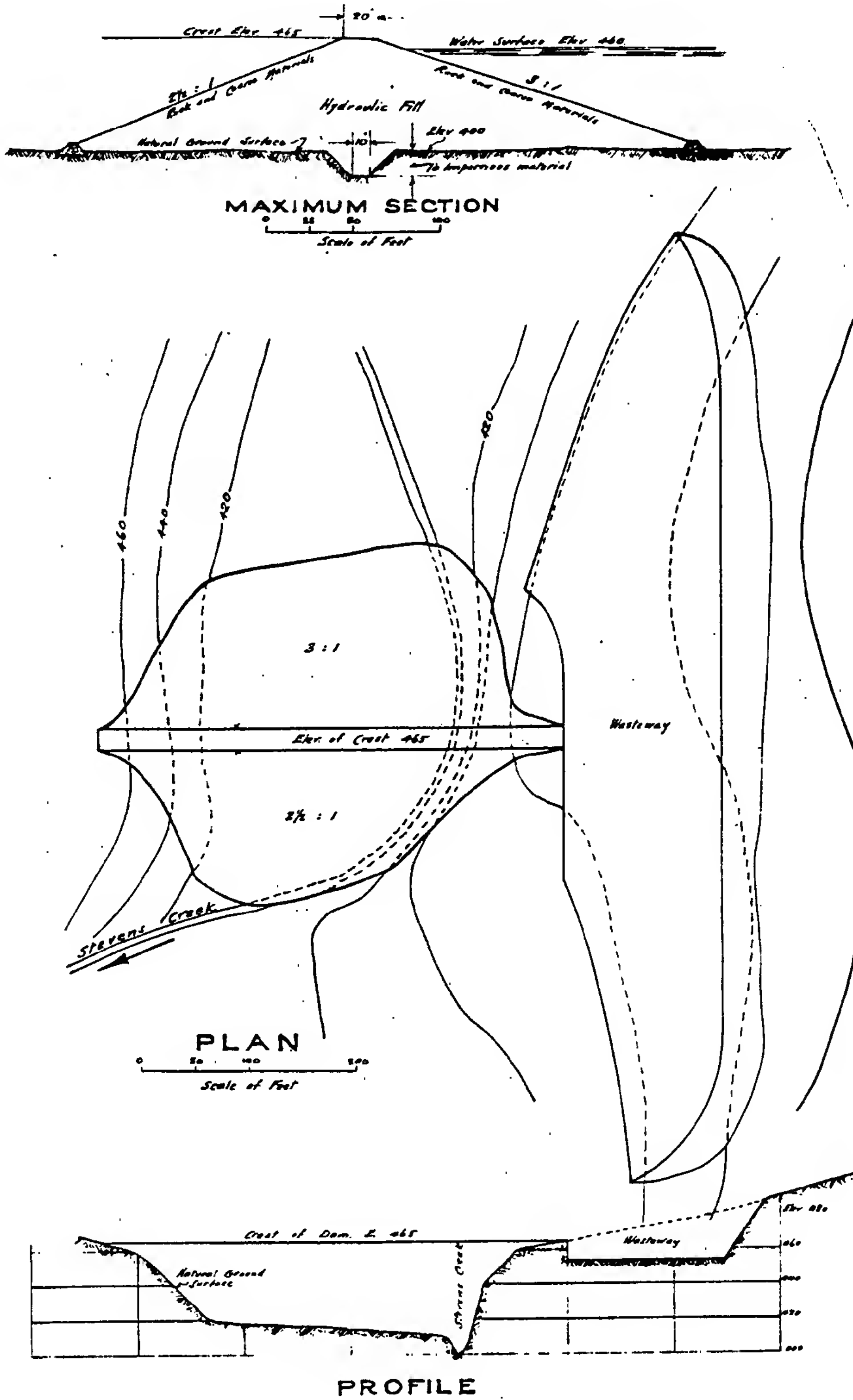
Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

Datum Assumed.

March 1921.

PLATE 55



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

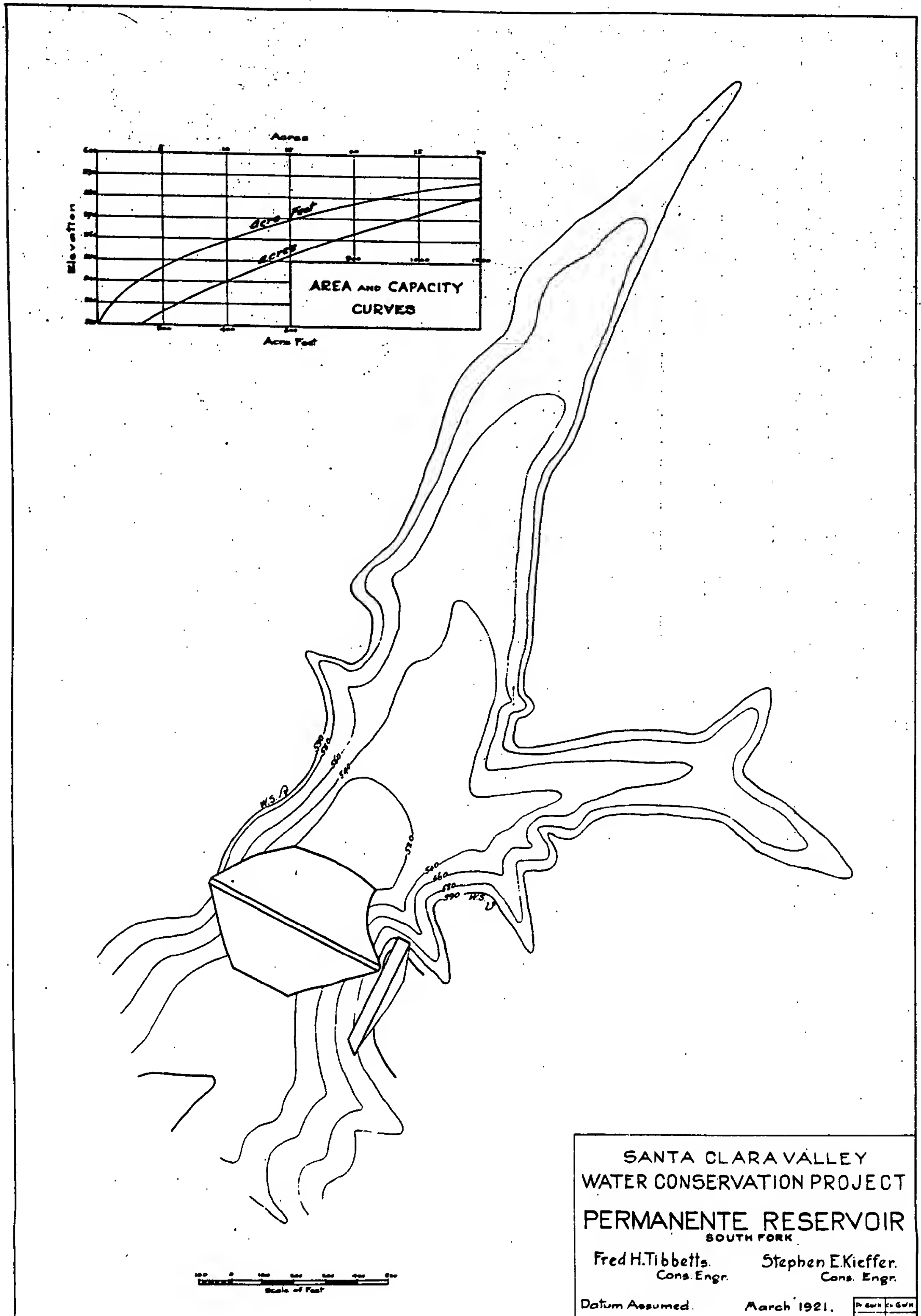
STEVENS CREEK DAM Nº3

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons Engr.

Datum Assumed.

March 1921.

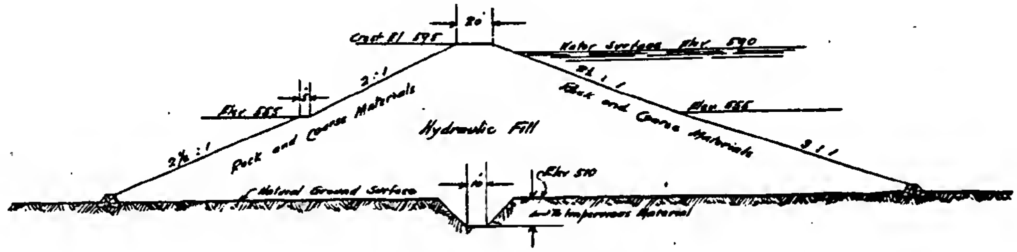


SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

PERMANENTE RESERVOIR
SOUTH FORK

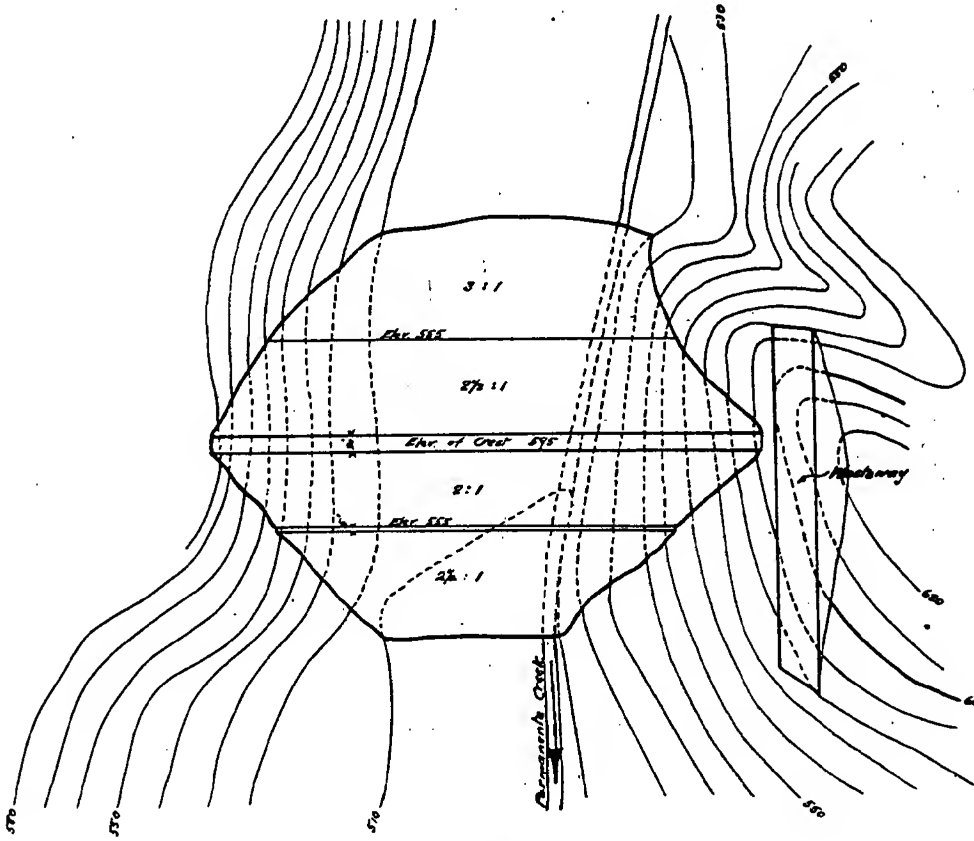
Fred H. Tibbetts. Cons. Engr.
Stephen E. Kieffer. Cons. Engr.

Datum Assumed. March 1921.



MAXIMUM SECTION

0 25 50 100
Scale of Feet



PLAN

0 50 100
Scale of Feet

PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

PERMANENTE DAM SOUTH FORK

Fred H. Tibbetts. Cons. Engr.
Stephen E. Kieffer. Cons. Engr.

Datum Assumed. March 1921.

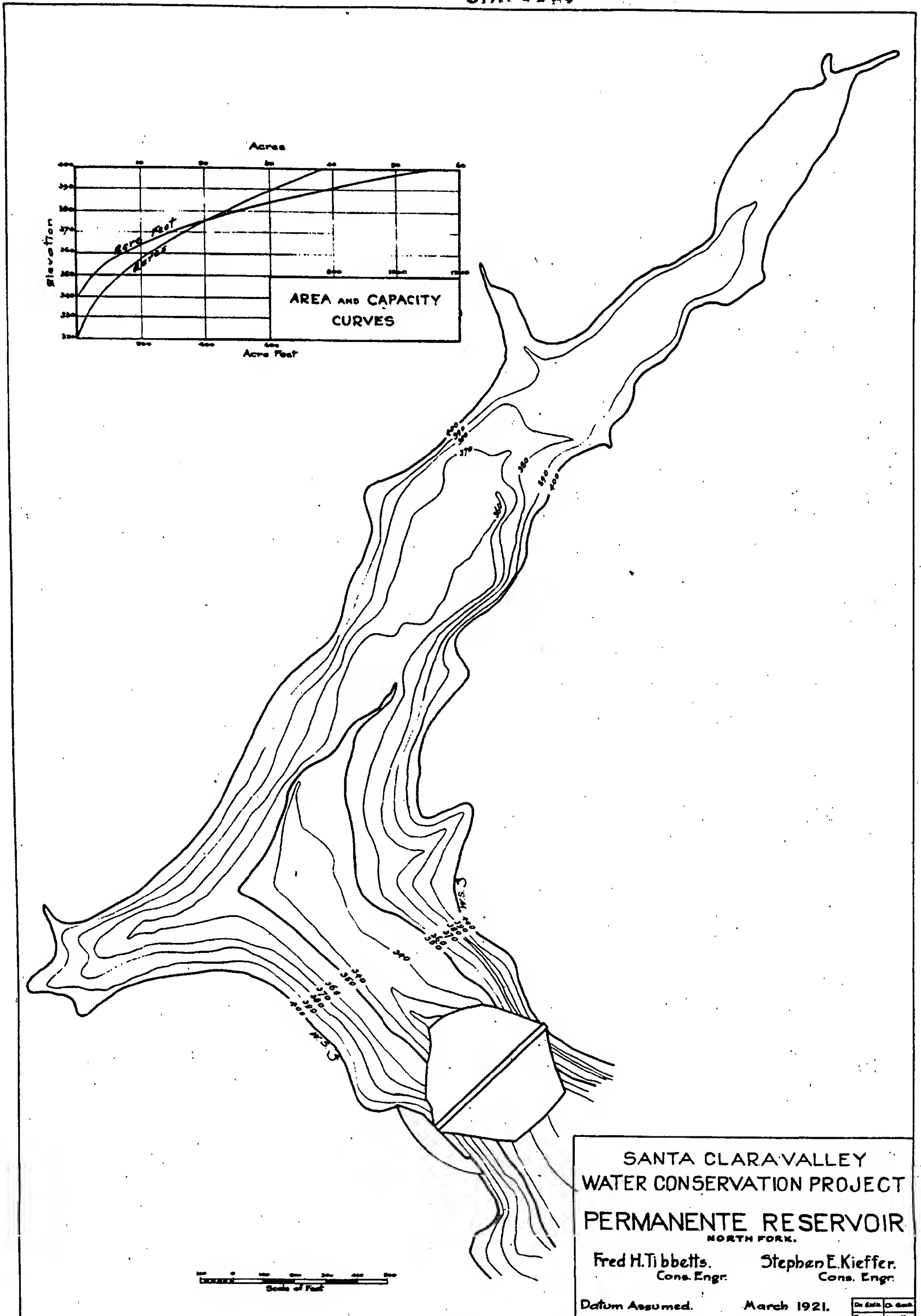
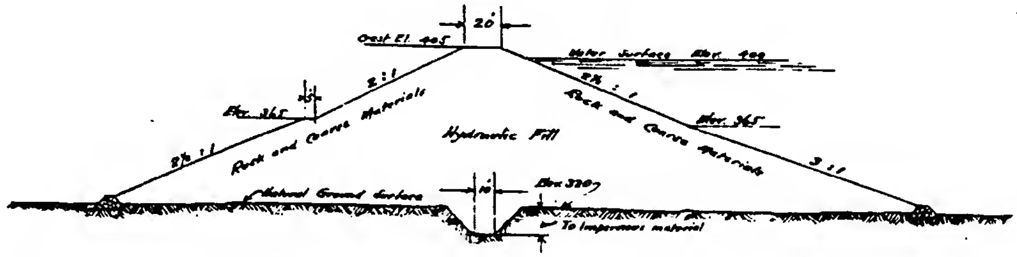
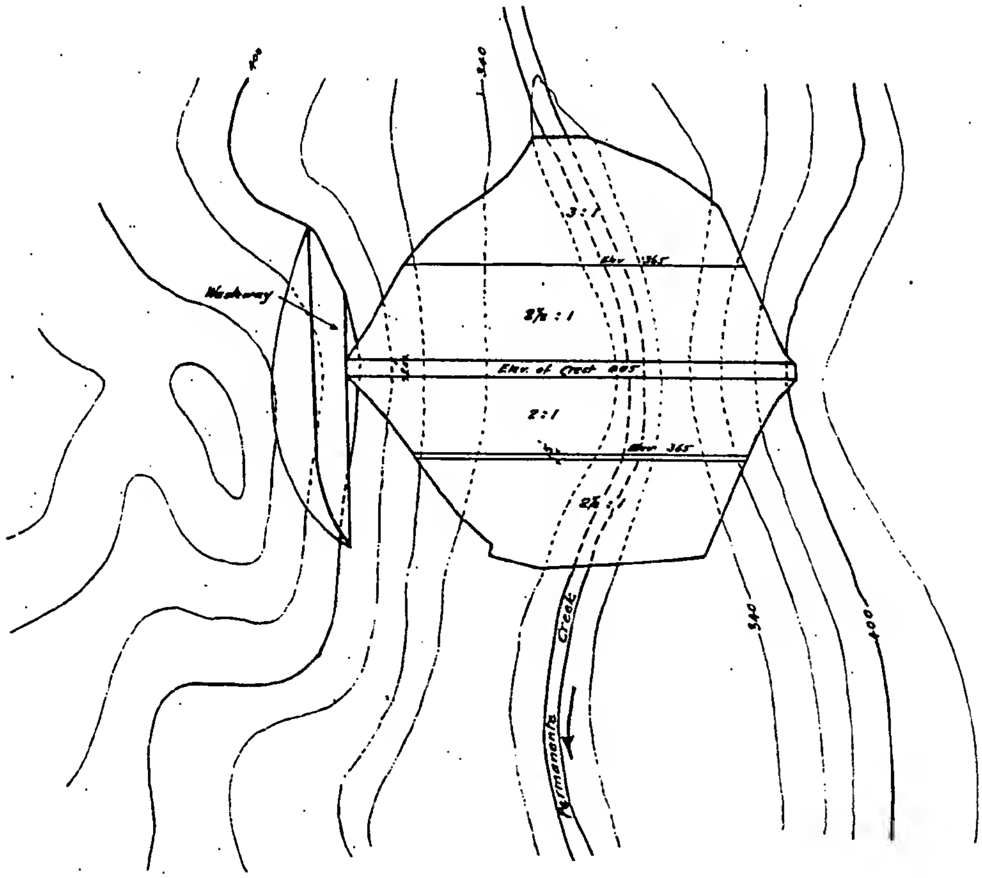

Acres
Elevation
Acre Feet
Acres
AREA AND CAPACITY CURVES
Acre Feet
W.S.
W.S.
Scale of Feet
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
PERMANENTE RESERVOIR
NORTH FORK.
Fred H. Tibbetts.
Cons. Engr.
Stephen E. Kieffer.
Cons. Engr.
Datum Assumed.
March 1921.

PLATE 59



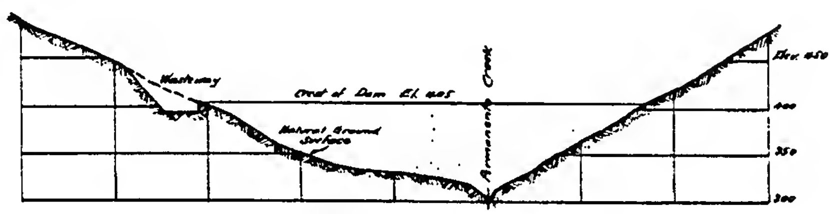
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



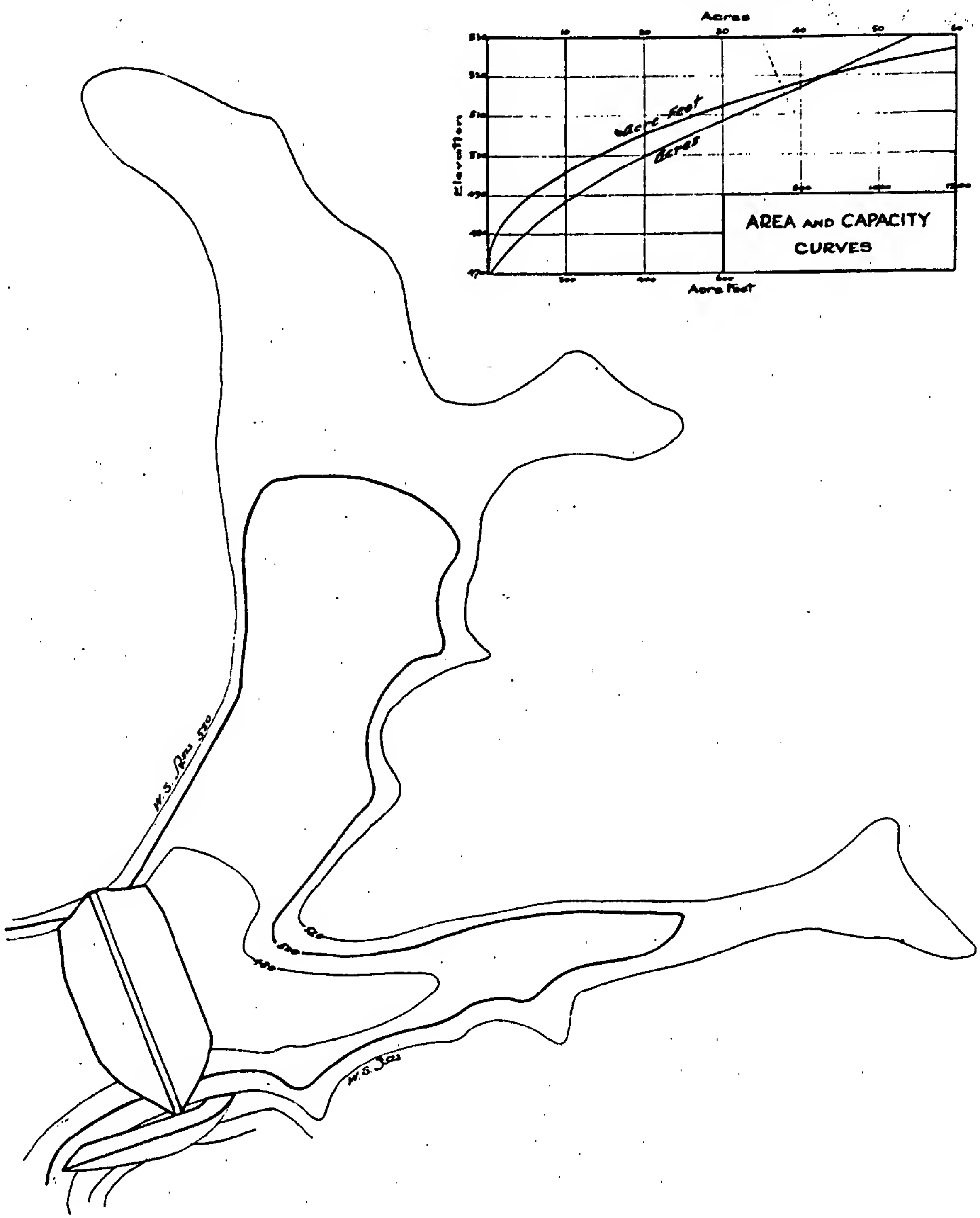
PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

PERMANENTE DAM NORTH FORK

Fred H. Tibbetts. Cons. Engr.   Stephen E. Kieffer. Cons. Engr.

Datum Assumed.   March 1921.



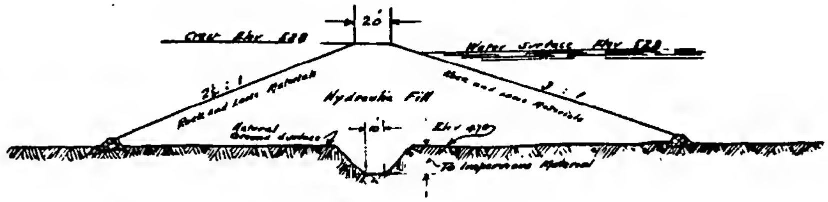
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

SAN ANTONIO RESERVOIR

Fred H. Tibbetts. Cons. Engr. Stephen E. Kieffer. Cons. Engr.

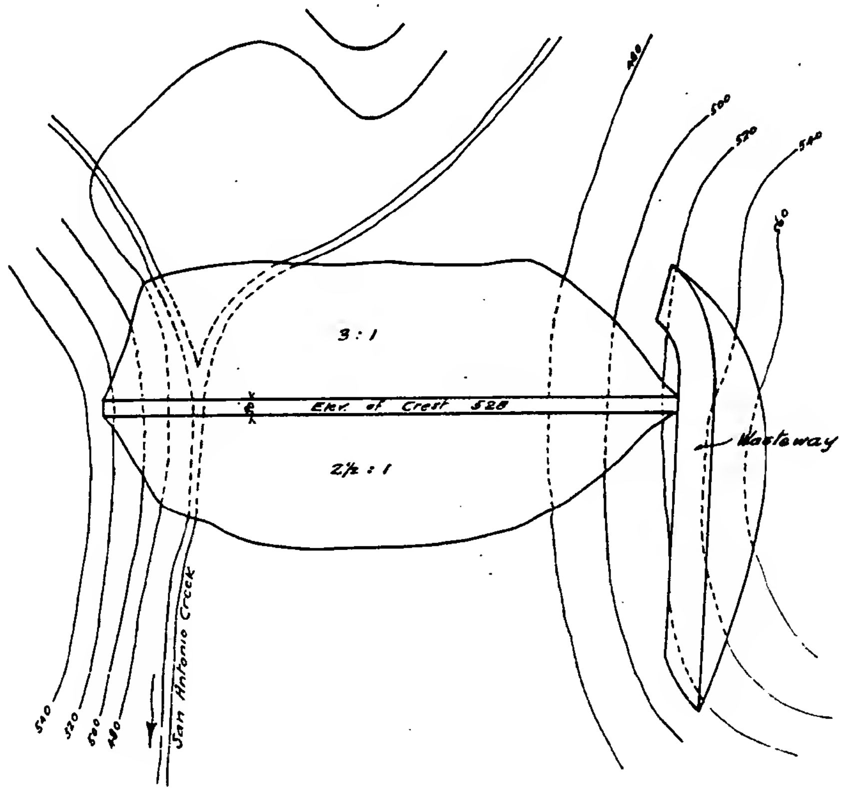
Datum Assumed March 1921.

PLATE 61



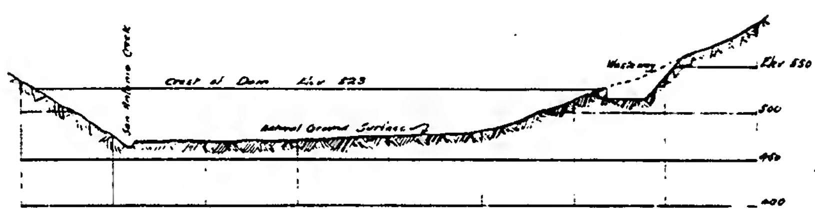
MAXIMUM SECTION

Scale of Feet



PLAN

Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

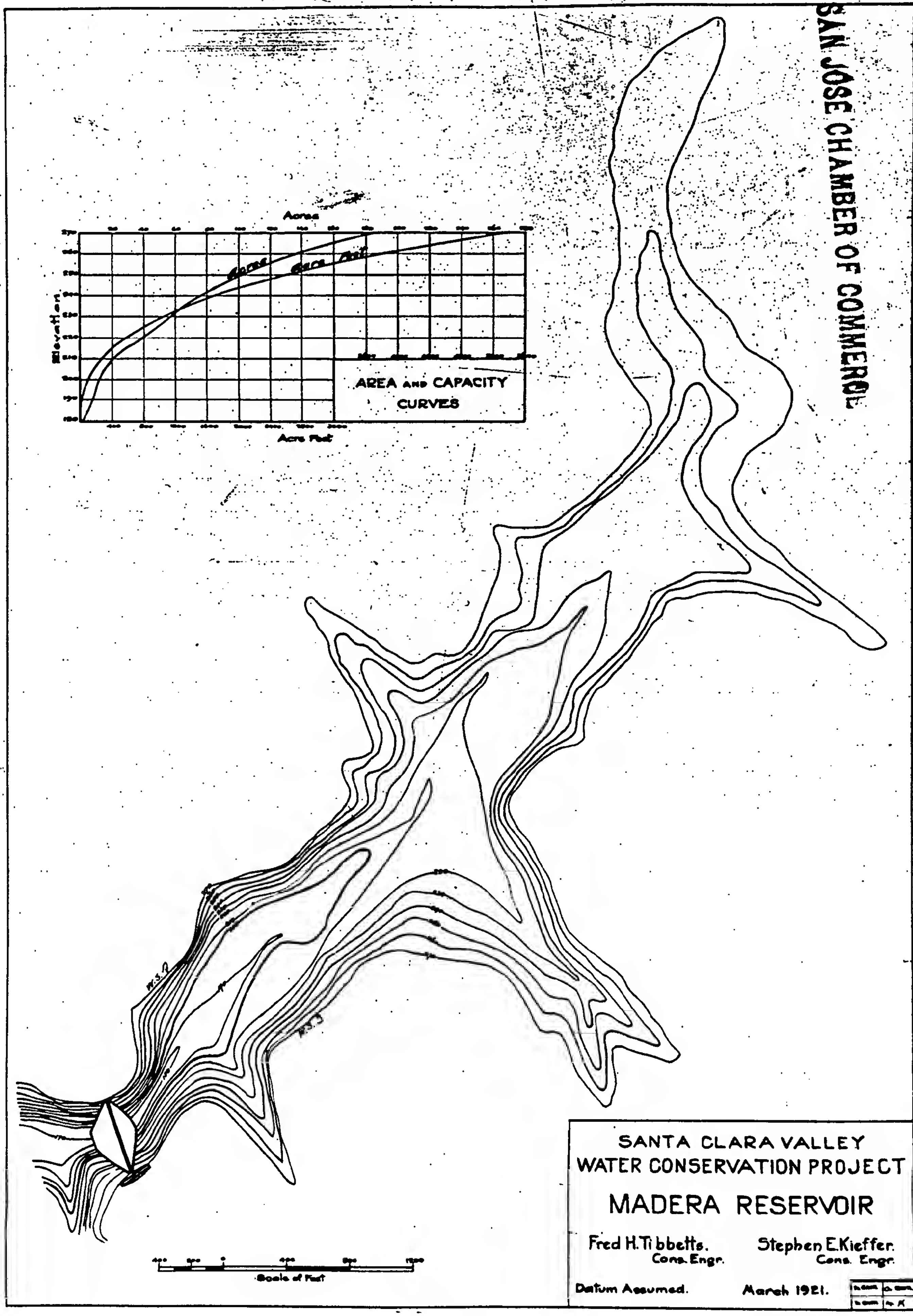
SAN ANTONIO DAM

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer
Cons. Engr.

Datum Assumed

March 1921.



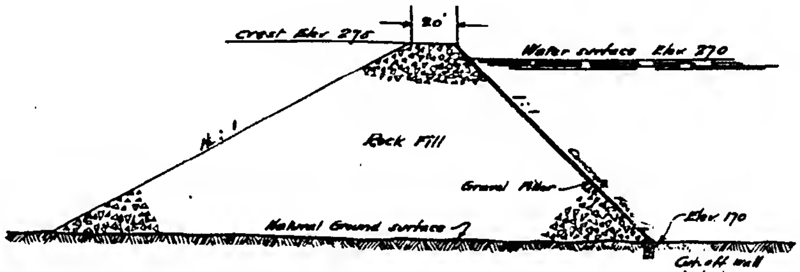
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

MADERA RESERVOIR

Fred H. Tibbetts. Cons. Engr.
Stephen E. Kieffer. Cons. Engr.

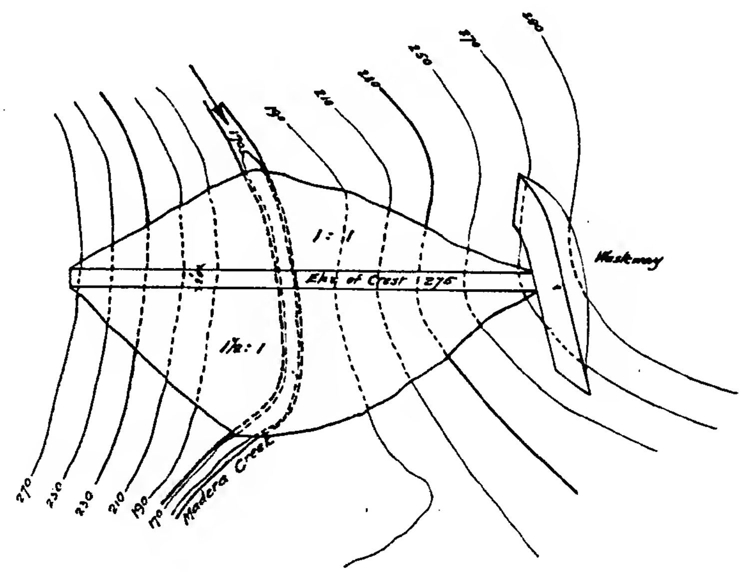
Datum Assumed. March 1921.

PLATE 63



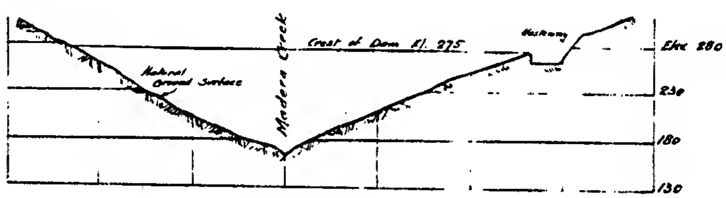
MAXIMUM SECTION

0 25 50 100
Scale of Feet



PLAN

100 50 0 100
Scale of Feet



PROFILE

SANTA CLARA VALLEY
WATER CONSERVATION PROJECT

MADERA DAM

Fred H. Tibbetts.
Cons. Engr.

Stephen E. Kieffer.
Cons. Engr.

Datum Assumed.

March 1921.

PLATE 64

volume of water passing through it. A small reservoir upon a stream of large, and largely torrential, flow will silt more rapidly, and have less relative value to a project, than where the reverse condition obtains. In view of the fact that many of the reservoir sites upon this project are relatively small, as compared with their tributary watershed and runoff, a careful study of the probable effect of silt deposits has been made.

This study is based upon data compiled from long time actual silting records for Searsville Lake, on San Francisquito Creek (F.C. Herrmann, Report to Stanford University, 1919). Searsville Lake was created by the Spring Valley Water Company in 1893. The original capacity of the reservoir was 1003 acre feet. In 1914 (21 years) the capacity had been reduced by silting to 474 acre feet. During this period the total estimated flow of water through the reservoir was 173,200 acre feet. The total deposition of solids was 530 acre feet, or 53% of the original capacity of the reservoir, equal to 2.52% per year. The ratio of solids deposited to total volume of water entering the reservoir was .306%.

Based on this record, which is particularly valuable because of its long time and local application, being upon one of the tributary watersheds of this project, the following table of probable sedimentation in each of the contemplated reservoirs has been prepared for the 18 year period from 1902 to 1920.

TABLE 18

ESTIMATED SEDIMENTATION IN RESERVOIRS BASED ON SEARSVILLE RESERVOIR

Stream	Res.Cap. ac. ft.	Total flow 18 years ac. ft.	Total deposits ac. ft. (.306%)	Deposits in % of Reservoir capacity. Total 18 yrs.	Annual
Coyote	120000	1,446,000	4410	3.67	.20
Uvas	30000	494,000	1510	5.03	.28
Llagas	20000	174,000	530	2.65	.147
Calero	9000	39,700	120	1.50	.084
Almaden	2500	114,500	350	14.00	.78
Guadalupe					
Upper	3500	58,300	180	5.15	.28
Lower	3000	64,300	190	6.33	.35
Calabazas	1600	29,700	90	5.60	.31
Stevens	6600	316,500	970	14.70	.82
Permanente					
N. Fork	1100	21,200	65	5.90	.33
S. Fork	1170	28,000	85	7.25	.40
San Antonio	1000	23,500	70	7.00	.39
Madera					
N. Fork Los Trancos) Diver.)	5000	45,200	140	2.80	.15
		(21 years)		(21 years)	
San Francisquito (Searsville)	1003	173,200	530	53.00	2.52

The above table is thought to be estimated upon a conservative comparative basis. The watersheds above most of the reservoirs, particularly those having the greatest discharge, are for the most part high, rocky and well forested, with small cultivated or open soil covered areas, and therefore liable to less relative erosion than prevails on the Searsville Lake watershed, where low rolling foothills and cultivated soil covered areas are more predominant.

During the flood period immediately following the storms of January, 1921, water samples were taken from each of the principal streams for the purpose of determining turbidity and suspended solids. (Figs.39,40,41) Comparative results are shown in the following table:

TABLE 19.

TURBIDITY AND SUSPENDED SOLIDS

Stream	Turbidity (Base 1.00 on scale)	Suspended Solids parts per 100000
Stevens	1.00	53.20
San Antonio	.77	33.12
San Francisquito	.59	9.56 (Influenced by Searsville Lake)
Los Gatos	.59	31.36
Coyote	.37	16.16
Campbell	.26	10.48
Permanente	.24	25.36
Calero	.14	1.84
Llagas	.13	7.52
Almaden	Trace	4.76
Guadalupe	Trace	4.16
Uvas	Trace	.08

The above table is not conclusive as to probable actual relative silt deposits. Streams high in color (turbidity) may be low in suspended matter, or the reverse. The heavier solids may be rapidly deposited, but the color resulting from finely divided materials may be long sustained. This is indicated on San Francisquito Creek, where there is an unknown influence due to the passing of a large portion of the stream flow through Searsville Reservoir, whereas, Stevens Creek is noted for its long sustained turbidity after floods, with accompanying suspended solids. There is no particular reason to think that the volume of solids carried by the waters from the San Francisquito watershed should differ materially from that delivered by the streams of the immediately adjoining watersheds.

FIG. 39

Uvas Creek Silt Sampling - 1/27/'21

FIG. 40

Llagas Creek Silt Sampling 1/27/'21

FIG. 41.

Calero Creek Silt Sampling. 1/27/'21

FIG. 42.

Los Gatos Creek upper spreading dam site.

The uniformly higher solid content of waters of the West side streams, as compared with those on the South and East, is apparent. The percentage of solids as shown (in table) by analysis of flood water samples is not sufficient to account for any material reservoir silting, and hence the results deduced from actual records of Searsville Lake are of the greatest practical value, and are believed to represent within reasonable limits the probable actual effect of sedimentation. It will be noted that whereas only 40 years will be required to completely fill with silt the Searsville Lake, it would require (at the same rate of deposit) from 120 to 130 years to fill the Stevens and Almaden reservoirs and from 250 to 500 years for the others. Even though the rate of sedimentation in the Madera, San Antonio, Permanente and Stevens Creek reservoirs was greatly increased over that for Searsville the effect would not be serious, due to the relatively large storage capacity compared to the total volume of stream flow. If found desireable inexpensive sluicing operations on the most affected reservoirs would permanently maintain their capacity. It is therefore concluded that materially lessened reservoir capacity from silting need not be feared on this project.

DAMSITES AND TYPES OF DAMS

On attached plates are shown the plan and profile of each of the damsites at the proposed reservoirs, together with a maximum section of a proposed type of dam. The types of dams selected for estimating purposes are those shown on the plates, but the careful investigations necessary for actual construction might change the type in some instances.

Funds for borings at the damsites were not available, but from available previous data on some sites and careful inspection of surface indications at all of the sites, combined with a general study of the geology of the locations, it is felt that the types of dams suggested can be successfully constructed. Final study may possibly extend the number of masonry structures, but a lack of knowledge at this time as to rock foundations has not justified their consideration. For the most part the canons at the damsites are wide and show no narrow rocky gorges, and the dams will accordingly be large per unit of storage. Because of the length of the structures, and the broken surface foundation material, the dams considered for most of the sites have been those of the hydraulic fill and loose rock fill types. These types were selected dependent upon the apparent volume and ease of obtaining the necessary materials. For the most part the soil cover is scanty and surface conditions indicate an abundant supply of suitable rock with very little stripping. Where suitable rock foundations are clearly defined the multiple arch type of reinforced concrete dam has been selected for estimating purposes. The sites and types for all dams are subject to change resulting from final investigation and study. In most cases, however, the location of the site is practically fixed by local conditions, but in a few instances there are alternate sites. The hydraulic fill dams will conform to the standard practice in construction, water for this purpose being obtained by pumping from the stream. The rockfill dams will be loose dumped, with manhandled and dry laid face wall and reinforced concrete facing as the water-tight element.

The following table gives the general physical data on each dam:-

TABLE 20.

PHYSICAL DATA ON DAMS

Name	Material	Maximum center Height (Feet)	Crest Length (Feet)
Coyote #1	Hyd. Fill	210	1085
Coyote #2	Rock Fill	150	1020
Uvas	"	130	1180
Llagas	"	125	800
Calero	Hyd. Fill	90	800
Almaden	Masonry	110	445
Guadalupe #1	Rock Fill	105	460
" #2	Masonry	100	385
" #3	Rolled Earth	83	1510
Calabazas	Hyd. Fill	108	480
Stevens #1	"	107	860
" #2	Masonry	125	410
" #3	Hyd. Fill	65	430
Permanente, S.F.	"	85	600
" N.F.	"	85	480
San Antonio	"	55	615
Madera	Rock Fill	105	500

UTILIZATION OF STORAGE RESERVOIRS

The utilization of water stored in surface reservoirs may be brought about in two ways -- through the agency of surface canals and pipe lines for direct surface irrigation, or by holding back the flood peaks for later gradual release into the stream beds for gravel absorption as a supply for pumping plants. Full utilization of the smaller reservoirs from the Alamitos and Guadalupe northward along the West Side may be had by either method, except for the Madera, whose utilization must be effected largely through the agency of surface distribution. For this reason special mass diagrams with draft lines have not been prepared for these reservoirs. Their effect in increasing conservation -- either by gravel absorption or surface use-is included in and indicated by the runoff and conservation mass diagrams shown on Plates 15 to 22

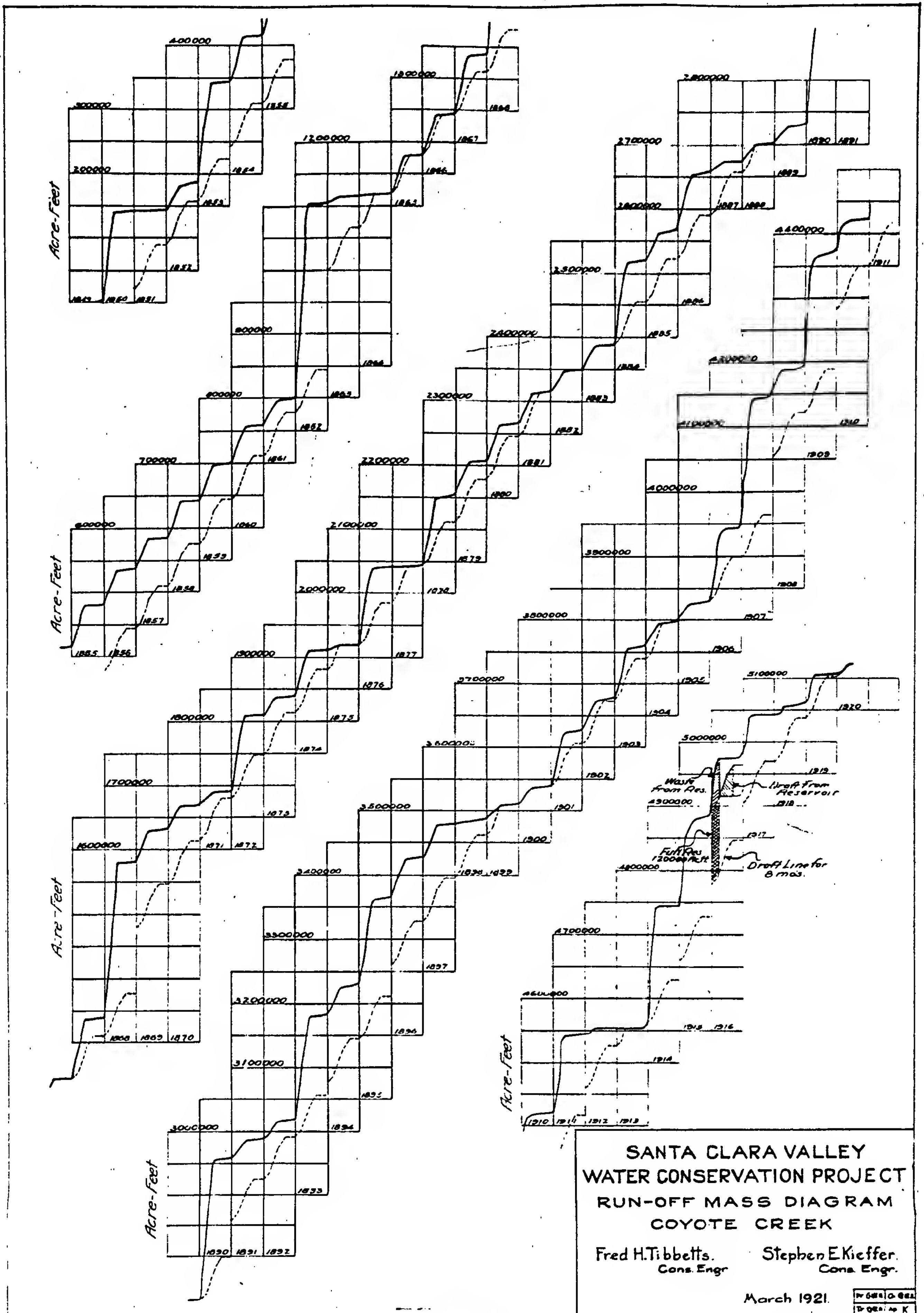
inclusive.

Such is not the case, however, with the Coyote, Uvas and Llagas, where a large portion of the water will certainly be drawn off in surface conduits.

Mass diagrams, showing special draft lines, have been prepared for each of these streams, and are shown in Plates 65 and 66. The results indicated by these special diagrams are also included in the general series of runoff and conservation diagrams, Plates 12, 13 and 14.

COYOTE RESERVOIRS

Because of the large storage capacity of the Coyote reservoirs there will be stored and made available for use a large quantity of storm water in excess of that required to replenish the Coyote gravels in accordance with the rulings of the Court covering that situation. In order to ascertain how much of this storm water can be diverted to use elsewhere in the Valley it will be necessary to stud y the problem of the Coyote runoff in some detail. For the purposes of this study the two Coyote reservoirs will be considered as one reservoir with capacity of 120,000 acre feet. A mass diagram for this stream has been plotted (Plate 65) by projection for the full 71 year period back to 1849. The relative runoff for the 18 year period from 1902-1920 is shown by inspection. From this diagram and the draft line shown it will be observed that with the storage provided almost exactly the same conditions of water supply would have prevailed in the dry periods of 1918-1920, 1912-1913, 1904-1905, 1890-1891, 1888-1889, 1874-1875, 1863-1864. On all other years a uniform and full supply of water would have been available. Hence when the 18 year period

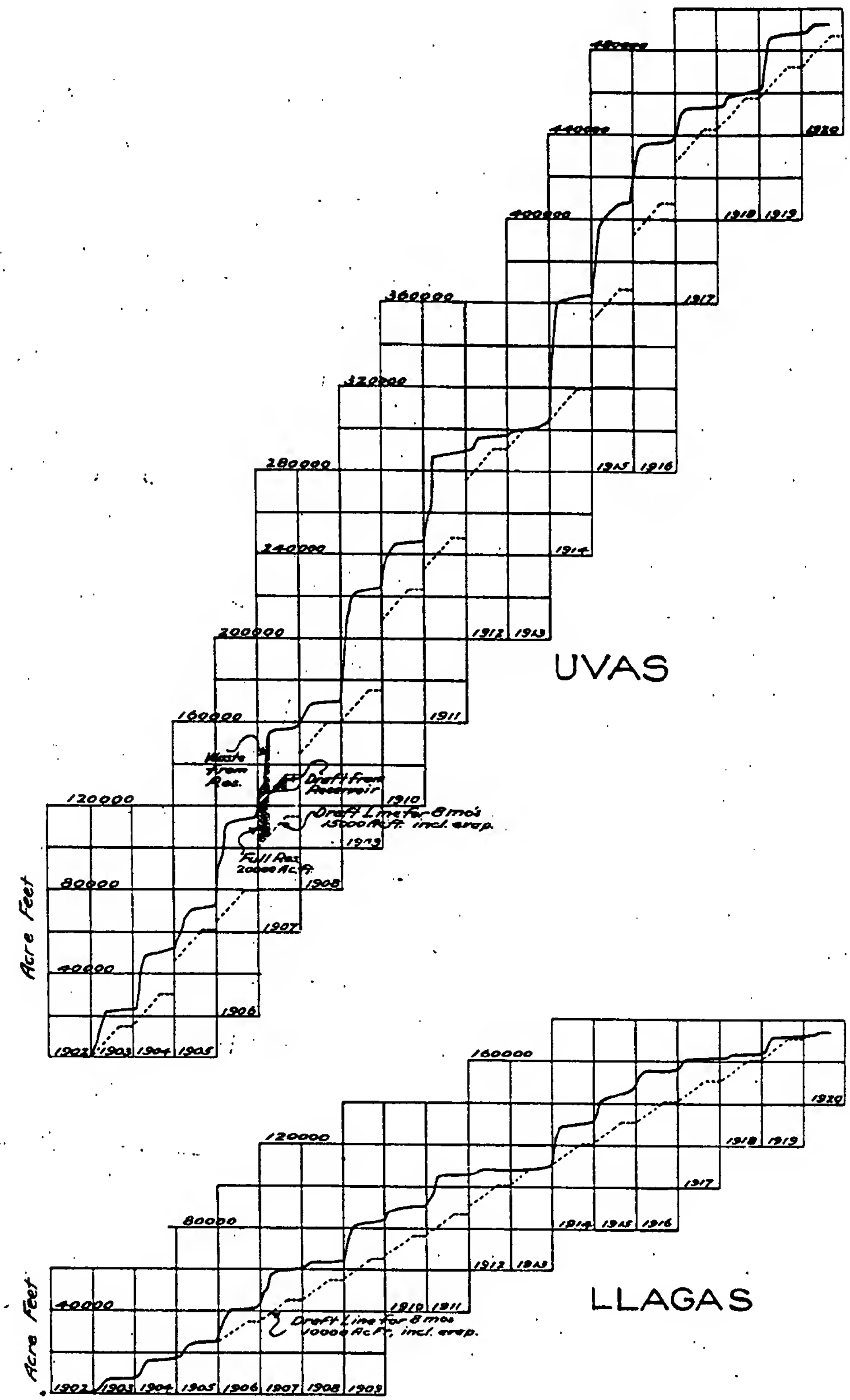


SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
RUN-OFF MASS DIAGRAM
COYOTE CREEK

Fred H. Tibbetts. Cons. Engr. Stephen E. Kieffer. Cons. Engr.

March 1921.

PLATE 65



SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
RUN-OFF MASS DIAGRAMS
UVAS AND LLAGAS CREEKS

Fred H. Tibbetts. Cons. Engr.   Stephen E. Kieffer. Cons. Engr.

March 1921.

PLATE 66

from 1902-1920 is taken as the basis of calculations the conclusions deduced should be expected with confidence to apply to a period of indefinite length.

We have already seen that the average seasonal discharge of the Coyote at Upper Gorge is 80380 acre fe~~e~~t, of which about 20,000 acre feet sink into the gravels and 60,000 acre feet escape to the sea, as determined by measurement.

By decree of the Court in the Hayes-Chynoweth vs. Bay Cities Water Co. case certain prescribed rules were laid down for apportioning water to the Coyote gravels, beyond which water might be diverted for use elsewhere in the valley. The "Rule of Replenishment" laid down was:-

> 820 million cubic feet (18800 ac. ft.) plus 6.6% of the stream flow thereafter, should be allowed to pass into the gravels each year at a rate that will permit of complete absorption.

In making its decree the Court accepted maximum figures throughout.

By this method the calculated replenishment for the five seasons (1902-1906) averages 23760 ac. ft., and for the 18 seasons (1902-1920) 20560 ac. ft. For the corresponding periods the measured averages were 22700 and 20500 ac. ft. The gaged absorption for the short time average included 6080 ac. ft. contributed from sources below the Upper Gorge, hence under the Court's rule of replenishment if an average of 23760 ac.ft. of water is released from the Upper Gorge <u>alone</u> an excess of 30% above the average calculated

or measured normal absorption for these gravels will be provided from that source. As indicated by the Miller (No. 1661), Heinlein, "Indicator" (Court) (No. 1716) and Bay Cities Water Co. #133 (Coyote) (#1724) wells the average absorption of about 20,000 ac. ft. per year has restored and maintained the water level in the wells during each of the years since 1902, except the dry years of 1912-13 and 1918-20, when the runoff was far below this average. The normal seasonal drop has averaged about 12 feet, with 18 and 22 feet for the dry periods. Within the Coyote Division, from the Upper Gorge to San Jose, there is a total area of 23860 acres and a net irrigable area of 16470 acres. The present irrigated area is 12156 acres, which will be amply supplied by the average of 20560 acre feet absorbed from the Coyote drainage above (say 16000 ac. ft.) and below (say 5000 ac. ft.) the Upper Gorge. To provide for irrigating the remaining 4314 acres an additional 7100 acre feet should be set aside from the Coyote storage, making a total average from this source of say 24000 ac. ft.

It is therefore concluded that if a regulated delivery from reservoirs of 24000 acre feet per season is provided from the Upper Gorge the full irrigation demands of the lands within the Coyote gravel absorption area will be met, with a normal maintenance of the level of the water table. The total average discharge of the Coyote (18 year period) was 80380 acre feet. This was distributed with a minimum of 3845 and a maximum of 202000 acre feet. With 120000 acre feet of storage an annual average draft of 66000 acre feet (including reservoir losses) could have been maintained (Plate 65), except in the dry years

of 1913 and 1920. With this storage and draft water would have escaped past the reservoirs in seven years to a total of 393000 acre feet, or an 18 year average of 21800 acre feet. It is possible to conserve this additional waste by increasing the storage to about 200,000 acre feet, which at some time may be justified, but is not considered here.

UVAS RESERVOIR

At the present time none of the Uvas water is available for the Santa Clara Valley. With a storage reservoir of 20000 acre feet capacity a gross draft of 15000, and net of 13700 acre feet could have been maintained in every year with waste past the reservoir except in 1913.

A storage of 30000 acre feet will make available an additional 5000 acre feet per year in all but the dryest years.

LLAGAS RESERVOIR

With 20000 acre feet of storage the full average flow of the Llagas can be made available, with a gross draft of 10000 and net of 8800, acre feet. A shortage would have occurred only in the years 1913 and 1920.

TOTAL AVAILABLE DRAFT FROM RESERVOIRS

The net available draft from the Coyote, Uvas and Llagas reservoirs in every year, except an occasional one of exceptional drouth, when the draft may drop to 40 or 50% of the normal, will be:-

Coyote	61000 acre feet
Uvas	13700 "
Llagas	8800 "

Of this the 22500 acre feet from the Uvas and Llagas, plus the 5000 acre feet of direct absorption from marginal valley watersheds, will amply care for the 16779 irrigable acres in the Morgan Hill-Gilroy area, and no part of this water is proposed to be diverted out of this area and its naturaldrainage southward.

Of the 66000 acre feet from the Coyote 5000 acre feet will go to reservoir evaporation losses (estimated at 48 inches per year), leaving 61000 acre feet net, of which 24000 will go to the Coyote area and 37000 to other parts of the valley.

An analysis of the water conserved under present conditions on the East Side, or Evergreen, section indicates that in order to guarantee the future irrigation of the entire 9300 acres in this territoy the natural absorption should be augmented by an average of 7000 acre feet per season from the Coyote storage. Deducting this leaves 30000 acre feet as the amount available from the Coyote to be diverted to the West Side.

WEST SIDE RESERVOIRS

The combined storage of the Calero, Almaden, Guadalupe, Calabazas, Steven Creek and Permanente reservoirs is 20170 acre feet. This water can either be utilized on the West Side by stream absorption or by surface use. In either event the total conservation with the aid of the reservoirs is shown on the mass diagrams on Plates 15 to 20. The average increase in conservation for these streams

due to storage is 13900 acre feet per year, or about 70%.

SAN ANTONIO AND MADERA RESERVOIRS

These reservoirs are treated separately because they are directly tributary to the Palo Alto area. The problem of augmenting the water supply of this area is complicated by the fact that Stanford University and the Bear Gulch Water Co. hold prior rights on the principal tributary watershed, that of San Francisquito Creek, and Stanford University contemplates using the available reservoir sites on that stream to conserve flood waters for the use of its property. Water from Los Trancos Creek will also be conserved by the enlargement of Felt Lake. The average maximum volume of water to be thus utilized is stated to be (Herrmann report to Stanford University) approximately 7600 acre feet net per season. Without this storage the only conservation to be effected on San Francisquito Creek proper is that due to natural absorption in the creek bed below the proposed reservoirs.

By constructing the San Antonio reservoir the natural absorption of that stream may be increased about 110%. The Madera reservoir has a possible capacity of 5300 acre feet and will permit of conserving the entire flow of Madera Creek and the major portion of the storm flow on Los Trancos Creek after deducting the Felt Lake storage.

The average regulated available water supply from the combined Madera, Los Trancos and San Francisquito is 4300 acre feet per season.

DESCRIPTION OF SPREADING DAMS

SOUTHERN CALIFORNIA DAMS

The spreading of flood water in order to artificially increase the stream replenishment of underground water basins, has been practiced extensively in Southern California for the last decade. The amount of water which it is possible to lose in the bed of a stream, depends upon the area exposed to percolation, and upon the rate of percolation. In general the areas exposed to percolation can be greatly increased by construction works. The Southern California streams, in particular the Santa Ana River at San Bernardino, and the San Antonio Creek, at Pomona, debauch abruptly from the mountains onto large deep cones, of coarse gravel and boulders. The main stream bed shifts in its rapid progress down this gravel cone, the bulk of the flow being confined to a comparatively small and unstable channel or "wash". The methods used to increase the percolation into these gravel cones have involved a series of low and inexpensive dams to widen the water surface in the main channel, together with a system, of divergent canals and ditches and in some cases ponds, spreading the flood water, fan-like over the cones. The results obtained by these methods have involved but small operating cost and are reported to be quite satisfactory, resulting in extensive re-plenishments of the underground gravels, from which water is pumped for irrigation from wells.

GENERAL PLANS FOR DISTRICT

The exact methods followed in Southern California are in general inapplicable for Santa Clara Valley because of the absence of the large coarse, steeply sloping, gravel cones. Similar results, however, are

believed to be possible, involving the use of the same general principles. In a number of smaller creeks with comparatively uniform channels, and especially where the channels are cut deep, the areas exposed to percolation can be expanded and the depth of water on the percolating areas increased, with a corresponding increase in the amounts of water disposed of, by the construction across the beds of the streams at frequent intervals of small and very inexpensive dams composed of gravel and boulders held in place by fine wire mesh. These structures will form level dams, or spillways across the entire width of the channels, possibly 2 to 4 feet in height. Such dams should be placed in favorable locations so as to form a series of steps with intervening pools. Beneficial results could probably be obtained at small expense by this method, on such streams, for example, as the Penitencia Creek, and the streams on the West Side such as the San Thomas Aquino, Campbell, Stevens, Permanente, Madero, San Antonio and San Francisquito Creeks. In the cost estimates of Chapter 6, no attempt has been made to fix the exact size, number, or location of such dams, but general estimates are given of the probable amounts which the writers deem might be beneficially spent in construction work of this type, providing that complete surface distribution is not deemed desirable.

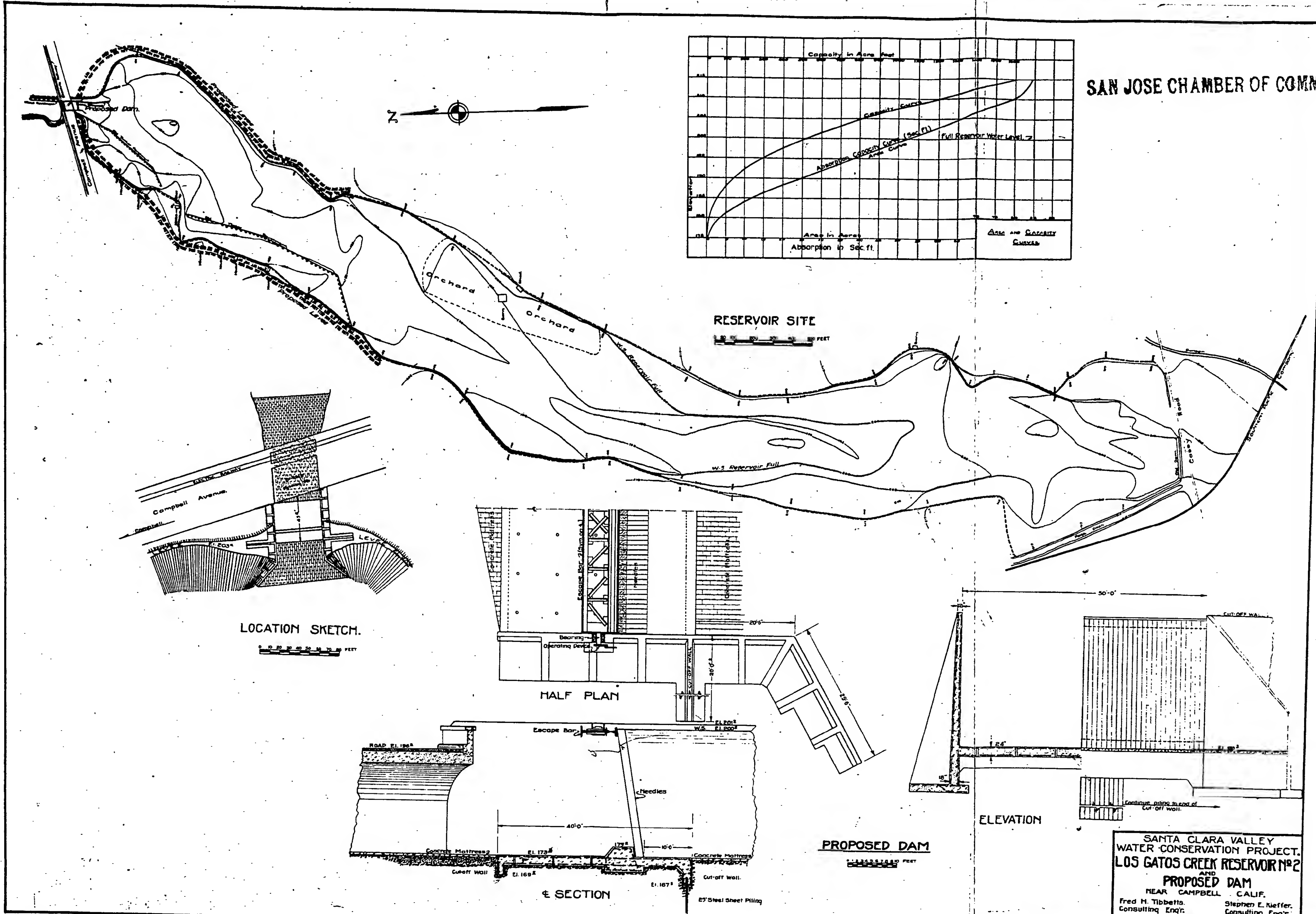
LOS GATOS CREEK - SPREADING DAMS

The principal construction work proposed for increasing the rate of percolation of water from stream beds is on the Los Gatos Creek, where this method of conserving water may be relatively of far greater importance than on other streams entering the valley. The annual average runoff of the Los Gatos Creek is about 42330 acre feet. The only important storage reservoir is at Lexington and is impractical because the S.P. Railroad runs through the bottom of the reservoir for a distance of several miles, and the cost of re-locating, or of otherwise providing for this railroad would be prohibitive. It is estimated that of the total runoff of 42330 acre feet an average of 14900 acre feet or 35 percent, reached the underground gravels by percolation, and that the balance of 27430 ac. ft., or 65 percent is wasted into the Bay, except for such relatively small amounts as are sometimes conserved by the surface irrigation ditches in the vicinity of Campbell.

Lower Dam:

Fortunately there are in this Creek Bed two large sites for spreading dams. The lower one of these immediately adjacent to the Town of Campbell, will furnish a large wide area of gravel beds, the overlying surface soil having been eroded, and the land rendered practically valueless, through the action of former floods.

The spreading area happens to be squarely in the center of the highly developed orchard section in which well depletion is at a most advanced stage. At the lower end of this gravel area, at the Campbell Avenue bridge, the creek bed narrows to its normal width of about 50 feet, with nearly vertical sides, about 20 feet in depth. Above this bridge it immediately widens out (Fig. 10) to an average width of about one-tenth mile, for a length upstream of about one half mile past the railroad bridge and up to the lower of the diversion dams for the surface ditches in this vicinity. It is proposed to construct a movable needle dam immediately above the Campbell Avenue bridge capable of raising the water to a total elevation of about 25 feet above the lowest point in the natural creek bed, at which height there would be submerged about 54 acres. This would raise the water about 4 feet above the natural ground level at the Campbell Avenue bridge so that the reservoir thus created would require leveeing around the sides of its lower end. For this purpose simple earth levees are suggested with a total height at the dam site of 7 or 8 feet, and a total length tapering out to no height at the upper end, of 4000 feet. The general construction of the proposed dam is shown on Plate 67, which also shows a map of the reservoir, with curves of storage, submerged area, and estimated rate of percolation, all as function of the depth of water against the dam. A special tripping device is provided, so that in case of floods, the needles holding the water may be entirely and instantly removed by tilting the beam which holds them at the top. It is believed that this device should completely remove any possible danger of damage from flood water. Above the dam the present destructive flood erosion would be entirely checked, as the creek would


Area and Capacity Curves
Capacity in Acre Feet
Area in Acres
Absorption in Sec.ft.
Elevation
Capacity Curve
Absorption Capacity Curve (Sec.Ft.)
Area Curve
Full Reservoir Water Level
RESERVOIR SITE
Proposed Dam
Proposed Levee
Orchard
W.S. Reservoir Full
Casey Road
LOCATION SKETCH.
Campbell Avenue
Levee
HALF PLAN
Concrete Mattress
Escape Bar
Bearing
Operating Device
Cut-off Wall
Needles
ROAD El. 196±
El. 201±
W.S. El. 200±
El. 173±
El. 169±
El. 167±
40'-0"
10'-0"
20'-0"
25'-6"
Concrete Mattress
Cut-off Wall
25' Steel Sheet Piling
℄ SECTION
PROPOSED DAM
50'-0"
24"
18"
Continue piling to end of Cut-off Wall.
ELEVATION
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.
LOS GATOS CREEK RESERVOIR No 2
AND
PROPOSED DAM
NEAR CAMPBELL CALIF.
Fred H. Tibbetts.
Consulting Eng'r.
Stephen E. Kieffer.
Consulting Eng'r.
March 1921.
U.S.G.S. Datum.

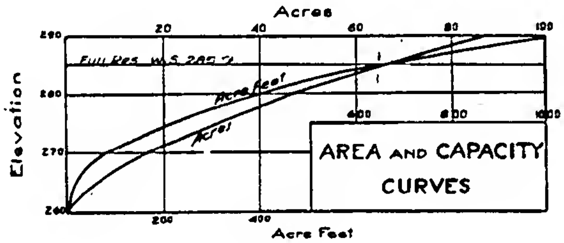
discharge into a lake or pond of quiet water. The assumed rate of percolation from the bottom of this reservoir is taken at the exceedingly low value of 2 feet per day, or 1 second foot per acre; less than the general average rate of seepage loss from the bed of an earthen canal. This rate was determined as the minimum of a number of actual measurements of the seepage loss from the creek running in its present channel, through this area.

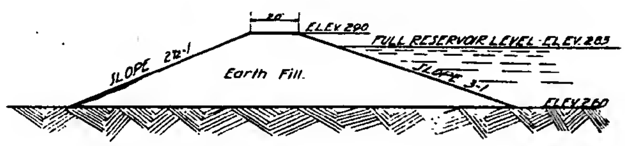
Upper Dam:

The Upper damsite is about two miles below Los Gatos, as shown on Plate 68, the proposed dam being located at the point where the railroad entering from the Northwest swings into the ravine, parallel to the Los Gatos Creek. (Fig. 42) At this point an earth dam of standard construction is proposed, with a total height of 30 feet. The spillway on the Northeastern end would be so designed as to give a maximum safe rate of passing flood water of 12000 second feet. This will automatically operate as an increased percolating area with a maximum area of 70 acres, and with a capacity estimated from actual measurements of percolation at this point of 2 feet per day, or 1 second feet per acre, or a total of 70 second feet. The underlying formation xx appears from the Geological Section to be more favorable for absorbing percolating waters than the lower site. Geographically the site is also in a more favorable location, being nearer the hills and above the main body of orchard land most in need of additional water.

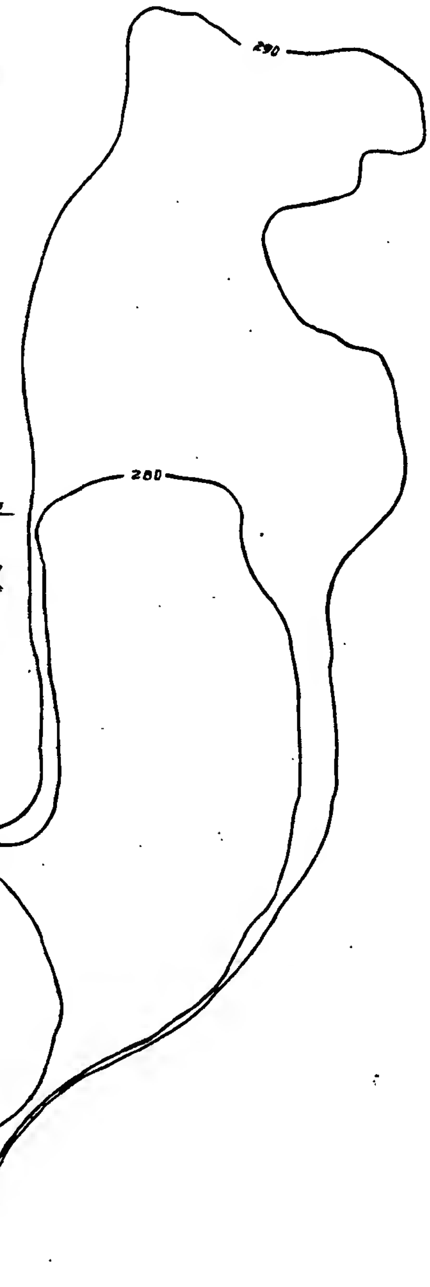
GUADALUPE AND ALMADEN CREEK SPREADING DAMS

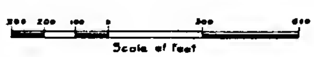
Immediately below the junction of the Guadalupe and Almaden Creeks about 6 miles South of San Jose, is a gravel spreading area somewhat





MAXIMUM SECTION OF DAM





SANTA CLARA VALLEY
WATER CONSERVATION PROJECT
LOS GATOS CREEK RESERVOIR No 1
AND
PROPOSED DAM
NEAR LOS GATOS CALIF.

Fred H Tibbetts, CONS ENGR
Stephen E. Kieffer, CONS ENGR

Datum Assumed
March 1921

PLATE 68

similar to that above the Campbell Bridge, although much smaller and with bank lines much less accentuated. A short distance below the Donner Avenue Bridge where the creek channel becomes relatively narrow, it is proposed to build a structure which will function in a fashion similar to that proposed at the Campbell Avenue Bridge on the Los Gatos Creek. The dam required will be much lower and wider. The maximum height of water proposed is elevation 190, giving a maximum depth of water, of but little over 5 feet. The total length of the dam is about 250 feet. The creek banks in this vicinity are quite low, and at the lower end of the reservoir would require low earth levees extending along the bank lines for about 2000 feet upstream on either side. The measured rate of percolation from the stream bed in this vicinity is unusually high, being about 4 feet per day, or about 2 second feet per acre. The total volume of the reservoir at the maximum elevation of 190 is 100 Acre Feet and the area submerged 45 acres. The total capacity of the reservoir for percolating water into the stream bed would then be about 90 second feet.

If ultimately found desirable, it would be entirely feasible to design a higher dam at this point, or to increase the percolating area by a number of small low rock dams, built by enclosing gravel and boulders in a wire mesh bag as previously described. A series of such dams could be located in the main creek bed below the Donner Avenue Dam, or could be located in either the Almaden or Guadalupe Creek beds above their junction.

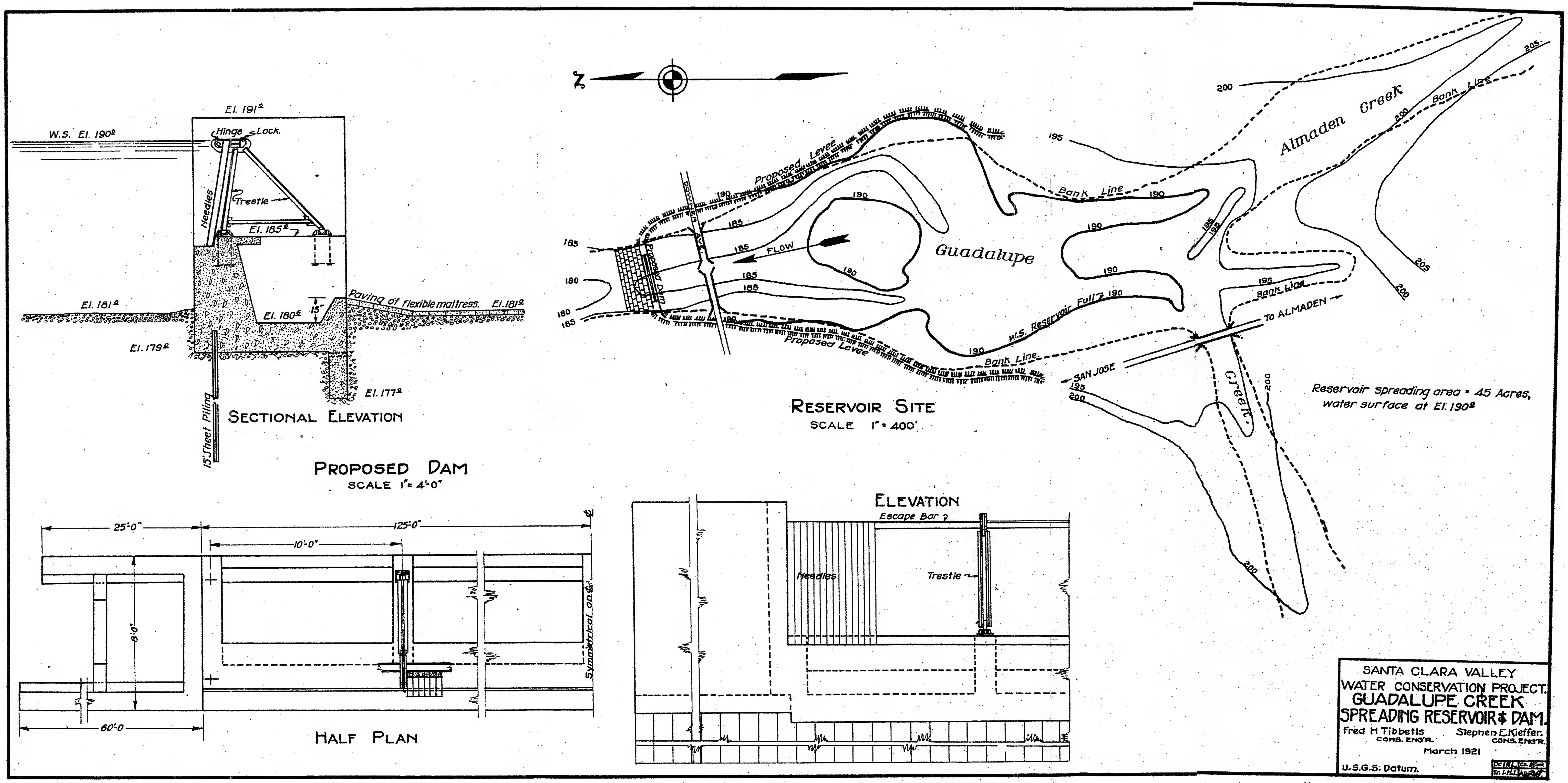

PROPOSED DAM
SCALE 1" = 4'-0"
SECTIONAL ELEVATION
W.S. El. 190.0
El. 191.0
Hinge
Lock.
Needles
Trestle
El. 185.0
El. 181.0
El. 180.0
15"
Paving of flexible mattress.
El. 181.0
El. 179.0
El. 177.0
15' Sheet Piling
HALF PLAN
25'-0"
125'-0"
10'-0"
8'-0"
60'-0"
Symmetrical on ℄
ELEVATION
Escape Bar
Needles
Trestle
RESERVOIR SITE
SCALE 1" = 400'
Proposed Levee
Proposed Dam
FLOW
Guadalupe
W.S. Reservoir Full
Bank Line
Almaden Creek
Creek
SAN JOSE
TO ALMADEN
Reservoir spreading area = 45 Acres,
water surface at El. 190.0
SANTA CLARA VALLEY
WATER CONSERVATION PROJECT.
GUADALUPE CREEK
SPREADING RESERVOIR & DAM.
Fred H Tibbetts
CONS. ENG'R.
Stephen E. Kieffer.
CONS. ENG'R.
March 1921
U.S.G.S. Datum.

PLATE 69

This general location for artificial replenishment of the underground water bodies, is especially favorable as the underground water contours indicate by their slope that water sunk in this vicinity would tend to travel northwestward toward the orchard sections below Campbell which are greatly in need of an increased water supply.

RE-USED GROUND WATER

Particularly in the Coyote and in the West Side Divisions of the District a material portion of the water distributed on the high lands will find its way to the underground water strata and be made available in the lower portions of the District for re-use. An exact analysis of the amounts and distribution of such return flow is impractical, but a general estimate may be made from careful measurements under similar conditions. Mr. C.H. Lee, now State Water Commissioner, found in the Owens River Valley, of the Los Angeles Aqueduct Project (See Water Supply Paper U.S. Geological Survey #294, Pg. 71), that about 50% of the water used for irrigation in the Owens River Valley is available for re-use by pumping lower down. Measurements of the Cache LaPoudre in Colorado (See Sep. No. 1, O.E.S. Bull. 158, 1904 Irrigation & Drainage Investigations, Pgs. 39 to 50) showed that about one-third of the water used for irrigation in the upper valleys reappeared in the stream bed lower down for re-use. Careful measurements by the State Engineer of Nevada in adjudicating water rights on the Walker River, showed that

approximately one-half of 234 second feet used for irrigation in Antelope Valley, reappeared and passed through the gorge between Antelope Valley and Smith Valley as underflow or surface flow. Similar conditions occur in the passage of the water from Smith Valley into the next lower Valley, which is much the largest of the three Valleys irrigated from the Walker River. This last example has been given in some detail because the topography is very closely analagous to that of the upper portion of the Coyote Division.

The Coyote Division is separated into three quite distinct valleys by rock spurs at the Lower Gorge and at the Narrows. (Fig. 8) The measuremenrs by the Bay City Water Company of absorption from the Coyote showed that an average of about 75% of such absorption occurred above the Lower Gorge, and about 15% above the Narrows, leaving only 10% between the Narrows and Julian Street, San Jose. It is the intention of the present plan to carry the releases for the Coyote Division from the reservoirs to a point near the Lower Gorge in cement lined canals for release into the creek beds, or for surface distribution as may later be desired. This conveyance of the water between the Upper and Lower Gorges in a lined canal is necessary to avoid super-saturation with resulting drainage, in that portion of the Coyote area which would occur if it was subjected to a continuous and uniform stream flow from the reservoirs during most of the year. It has been shown by measurements that below Julian Street, San Jose, the Coyote is a "making stream". The Coyote Division has accordingly been segregated into up-lands above San Jose

and Easterly, and low-lands below this point. It will now be assumed that one-half of the water released for irrigation or stream absorption in the up-land area of the Coyote is available for re-use in the low-land area.

Similar conditions exist in the West Side Division and in estimating stream absorption it has been assumed that there is no absorption below a line approximating the Southern Pacific Railroad. The West Side Division will accordingly be divided into up-land and low-land areas using the railroad as a division line. There is no marked barrier, however, to the underflow comparable to the rock gorges at the Narrows and Lower Gorge of the Coyote. The slope of the surface contours, as well as of the underground water contours indicates that re-usable water from the West Side area is probably uniformly distributed over the low-lands of West Side and Coyote areas and it will be assumed that one-fourth of the water used on the up-land area of the West Side Division will become available for re-use in the low-land areas of both divisions.

In addition to these amounts directly available for the low-land areas, there will be available amounts for second re-use, and which unless intercepted, might otherwise escape under the marginal marshes of the lower San Francisco Bay. It is planned to intercept these escaping amounts of water by lines of pumped wells to supply the Palo Alto and Milpitas Divisions.

Based upon the above deductions, the following Table 21 shows the gross requirements for the West Side, Coyote, Evergreen and Milpitas Divisions as developed from the duty of water requirements of Capter III, together with the portion of these gross requirements which will be available from primary sources of stream absorption and reservoir releases, and the portion available from re-used water in the low-lands.

TABLE 21

AMOUNT AND SOURCE OF RE-USABLE WATER

DIVISION	Total Water Requirements Up-Land Area	Estimated Return Water	Available for Use in: Coyote Div.	West Side Div.	Milpitas Div.
	Ac.Ft.	Ac.Ft.	Ac.Ft.	Ac.Ft.	Ac.Ft.
West Side	82500	20600	9400	11200	
Coyote	29000	14500	14500	--	
Evergreen	13300	3325 (1)	--	--	3325 (1)
TOTAL	124,800	38,425	23,900	11,200	3,325

TOTAL WATER REQUIREMENTS AND AVAILABLE WATER SUPPLY

DIVISION	Total Maximum Water Requirements	Available Supply: Primary Sources	Re-used Water
	Ac.Ft.	Ac.Ft.	Ac.Ft.
West Side	109,100	97,900 (2)	11,200
Coyote	52,500	29,000 (3)	23,900
Evergreen	13,300	13,300 (4)	--
Milpitas	7,800	4,475	3,325 (1)
TOTAL	182,700	144,675	38,425

Notes

(1) Return Water from Evergreen Division assumed to pass to lowlands of Coyote Division and be recovered for use in Milpitas Division by proposed well pumping plants.

(2) 73,900 Ac.Ft. from water sheds of West Side Division and balance from Coyote Reservoirs.

(3) 24,000 Ac.Ft. from Coyote Reservoirs and balance from adjacent watersheds.

(4) 6,300 Ac.Ft. from watersheds of Evergreen Division and balance from Coyote Reservoirs.

TABLE 22.

CONSERVABLE WATER FROM PRIMARY SOURCES

1902 - 1920

STREAM	Maximum Ac. Ft.	Minimum Ac. Ft.	Average Ac. Ft.	% of Runoff
Penitencia	5,050	1,010	2,975	30
Coyote	69,865	26,800	58,890	73
Uvas	13,700	8,000	13,400	49
Llagas	8,800	1,570	8,215	74.5
Almaden & Guadalupe	36,750	2,840	19,045	96.5
Los Gatos	38,540	5,100	23,785	56.5
San Tomas	3,020	300	1,550	74
Campbell	14,760	1,410	8,855	75
Calabazas & Stevens	29,070	2,560	16,750	81
Permanente	4,480	370	2,485	89
San Antonio	2,290	195	1,305	75
Madera, Los Trancos & San Francisquito	8,150	1,095	4,300	39
Minor Watersheds	35,500	1,550	15,930	95
TOTAL	261,040	57,695	177,480	69

TOTAL AVAILABLE WATER SUPPLY

Based on the analysis of the total tributary water supply of the Valley, as set forth in Chapter IV, the foregoing study gives the total water supply available for beneficial use if conservation measures are fully applied. The total available supply is shown in tabulated form in Table 22, and graphically for the entire valley on Plate 1 (Frontispiece) and for each of the main streams on Plates 11 to 22.

The water shown to be thus available for the last 18 years averaged 177,480 acre feet per year, or 69% of the runoff, with a maximum of 261,040 and minimum of 57,695 acre feet. The average yearly water available from the primary sources described augmented by re-used water, which is the secondary source of supply, is 215,900 acre feet. To this may be added a possible 20,000 acre feet from the Coyote and 5,000 acre feet from the Uvas when the demand becomes such as to justify the expenditure for practically full conservation on those streams.

CHAPTER VI

CONSTRUCTION PROGRAM AND COST ESTIMATES

GENERAL

The construction program upon which general estimates are based is predicated upon four general lines of procedure: -

1. Construction of Storage Reservoirs.
2. Construction of the Conduits required to deliver water from the reservoirs to initial or central points of use.
3. Construction of Spreading Works on Stream Channels.
4. Construction of Central Well Collection, and Pumping Plants in lower end of Valley near San Francisco Bay.

The province of this report is construed to cover the present water conditions and the possible changes in those conditions resulting from a general program of conservation of waste waters, together with an outlined plan of main conduits and works to deliver the conserved water into the various portions of the Valley at united or central distributing lines or points.

It is clearly not practicable or advisable at this time, from the standpoints of time or funds, and in advance of legal organization, and the necessary detailed study of the local needs and wishes of irrigators in the various sections, to attempt analyses of the detailed problems of distribution and use of water. This is the second step in the program, and can only come after legal organization of the District.

The construction program is, therefore, concerned with conserving the waste water and carrying it to common points for such detailed use as circumstances may direct, this preliminary program being essential to and the same for any method of distribution.

On the general map of the District (Plate 70) the locations of main conduits as tentatively laid out are shown. The general scope of the proposed works in outline is as follows: -

Water from the Uvas and Llagas reservoirs to be carried in open canals to three points on the hills at the West Side of the Valley, from which pressure pipes will convey the water across the Valley to the East Side. From these canals and centrally located pipes distribution in any manner desired can be effected.

Water from the Coyote will be delivered from the reservoir into the stream channel, and thence diverted by canals and pipes to the East and West sides of the main Valley.

Water from streams on the West Side will be carried in canals along the western margin of the Valley.

A portion of the Palo Alto and all of the Milpitas section will be provided with water from groups of wells and central pumping plants located along the margin of the Bay.

It must be clearly understood that the capacities here assigned to the various conduits and pumping plants are tentative only, and subject to the revision of detailed study to meet the needs of each locality. The general layout proposed is for estimating purposes, and has been made liberal. Refinement of detail will not change the general scope of the plan.

DESCRIPTION OF PROPOSED WORKS

1. RESERVOIRS

A brief description of the proposed reservoirs and dams is given in Chapter 5. Further detail is shown on Plates 31 to 64, inclusive. Locations of these reservoirs are shown on Plate 30.

2. CANALS AND PIPE LINES

Uvas and Llagas Conduits for Morgan Hill-Gilroy Division.

(a) Uvas reservoir to junction with Lion Ranch branch at Sycamore Ave. 2-1/4 miles open canal, with capacity 40 cu.ft. per sec.

(b) Lion Ranch - Church Road Conduit. 3 miles open canal to point hills. 1-1/4 miles 24" & 2-1/8 miles 20" pressure pipe to East Side Valley along Church Road. Capacities from 20 to 10 cu.ft.per sec.

(c) Uvas conduit from Lion Ranch branch to junction with Llagas conduit. 3 miles open canal. Capacity 20 cu.ft.per sec.

(d) Llagas reservoir to junction with Uvas conduit. 2 miles open canal. Capacity 20 cu.ft.per sec. Diversion dam in Llagas Creek below reservoir.

(e) Main conduit Uvas. Llagas junction to Spring Ave. 3/4 mile open canal with capacity 40 cu.ft.per sec.and 1-1/4 mile,with capacity 20 cu.ft.per sec. 4/10 miles,28" pressure pipe siphon.

(f) Spring-Diana Ave. Conduit 1-1/2 miles 34" and 1-1/2 miles 24" pressure pipe across Valley. Capacity 20 to 10 cu.ft.per sec.

(g) Watsonville Road- Middle Ave. conduit- 2 miles 26" and 2 miles 20" pressure pipe across Valley. Capacity 20 to 10 cu.ft.per sec.

Coyote Conduits for West Side and Evergreen Divisions: It is proposed to deliver water from Coyote Reservoir #1 into the channel of Coyote Creek, down which it will flow about 1-3/4 miles to a diversion weir at the head of the main canal. From this point the main conduit with a capacity of 200 cu. ft. per sec. will proceed along the hills on the East Side of the valley as far as Bailey Ave., where it will cross to the West Side. At this point the water required for Coyote gravel replenishment and the Evergreen Division will be dropped into the creek and allowed to flow down the channel through the Lower Gorge. Near the Edenvale Narrows a diversion weir will pick up the water for the Evergreen Division, which will be conducted in a canal along the East side of the Valley to Reed Ave., beyond the Story Road. Here a pumping plant will lift the water 75 feet to a higher level conduit, which will continue northerly along the hills to Milpitas Lane. Returning to the Coyote at Bailey Ave. the main West Side conduit will cross by pressure pipe to the hills West of Coyote Station, and thence along the western hills by open canal to the point of the Santa Teresa Hills, near the junction of Alamitos and Guadalupe Creeks. From this point the main conduit will follow approximately the 200 ft. contour northward through Campbell and the central West Side to Stevens Creek. A branch from the main conduit will pass southward from the point of the hills to and across Alamitos Creek, near the Pioneer School, where a pumping plant will lift the water to a 300 ft. level West Side marginal conduit. The water thus lifted will augment the flow of the Alamitos and Guadalupe for the area between the 200 and 300 foot levels. These conduits are briefly described as follows: -

(a) Coyote reservoir to point of canal diversion, 1-3/4 miles: no conduit.

(b) Main Canal - 2-1/2 miles: Cap. 200 cu. ft. per sec.

(c) Utitilze small creek bed. 7/8 miles; no conduit.

(d) Main Canal to Coyote River crossing, 1-7/8 miles.

(e) Coyote crossing to Main Highway, 1/2 miles, 52" concrete pipe: capacity 100 cu. ft. per sec.

(f) Along Highway to Laguna Seca Hills. 1-1/2 miles: 60 inch concrete pipes.

(g) Laguna Seca Hills to point Santa Teresa Hills: 9-1/2 miles open canal. Capacity 100 cu. ft. per sec.

(h) Santa Teresa Hills to Los Gatos Creek: 5-1/2 miles canal; 80 cu. ft. per sec.

(i) Los Gatos Creek to Stevens Creek: 9-3/4 miles; 50 to 20 cu. ft. per sec.

(j) Santa Teresa Hills to Alamitos Pump Station: 7/8 miles; 20 cu. ft. per sec.

(k) Alamitos Pump Station.

(l) 30" pressure pipe Alamitos Pump Sta. to High Level Canal from Alamitos Creek: 1-1/8 miles.

An alternative plan to reach the West Side high level canal entirely by gravity from the Coyote has been considered and studied. This plan consists of a canal leaving the Coyote Reservoir Dam #1 at an elevation of 425 feet, and by a continuous lined canal and high pressure siphons across the Coyote and Alamitos Valleys, reach the West Side Canal. This conduit being at a high level will traverse throughout its length a difficult country with expensive siphons, and its costs condemns it as compared with the low level project. The additional cost for the high level over the low level conduit will necessitate an annual and perpetual fixed charge on the capital invested, whereas it is estimated that the Alamitos and Guadalupe high level supplies will only need augmenting from the Coyote in 1/3 or 1/2 of the years, during which time only the pumping plant need be operated. Hence this plan will not be further considered.

<u>High Level West Side</u>: Beginning at diversion weirs on the Alamitos, a high level West Side Conduit will pass northward along the hills and pick up water from the Guadalupe, Los Gatos, San Tomas, Campbell, and Calabazas Creeks, and terminate at Stevens Creek. A still higher conduit will divert from Calabazas Creek to supply land above the last named conduit between Campbell and Stevens Creeks. A conduit diverting from Stevens Creek will pass northward along the District boundary as far as San Antonio Creek, and pick up water from Permanente Creek. Details are as follows: -

(a) Alamitos diversions to Alamitos Siphon, 8½ miles, 20 cu. ft. per sec.

(b) Alamitos Siphon to Guadalupe Creek, 1 mile, 40 cu.ft.per sec.

(c) Guadalupe Creek to Los Gatos Creek, 5 miles, 50 " " " "

(d) Los Gatos Creek to Stevens Creek, 9½ miles, 40 to 20 " "

(e) Calabazas Creek to Campbell Creek, 1-3/4 miles, 50 " " "

(f) Calabazas Creek to Stevens Creek, 4 miles, 10 cu.ft. per sec.

(g) Stevens Creek to Permanente Creeks, 2½ miles, 30 cu.ft.per sec.

(h) Permanente Creek to San Antonio Creek, 4½ miles, 20 cu.ft.per sec.

<u>East Side - Evergreen</u>

(a) Coyote Creek Diversion Weir.

(b) Canal along East side from Diversion Weir to Pump Sta. at Reed Ave. 10-3/4 miles, 20 cu. ft. per sec.

(c) Reed Ave. Pumping Station.

(d) Canal from Pumping Station to Milpitas Lane, 4-3/4 miles, 10 cu.ft. per sec.

<u>Palo Alto Division</u> : A conduit diverting from San Antonio Creek will pass northward along the West line of the District,picking up water from Madera Creek

This conduit will be about two miles in length with maximum capacity of 20 cu. ft. per sec., and will serve the higher levels of this Division. San Antonio and Madera Creek channels are available as conduits to serve lower diversion points and surface conduits if so desired.

GENERAL TYPE OF CONDUITS AND PUMPING PLANTS

Canals: Open canals are proposed in all locations where gravity conduits are practicable, except along highways and at principal road crossings. The average grade for all canals will be 4 ft. per mile. Side slopes will be 1 to 1, and bottom widths, dependent on carrying capacity, will vary from 2.5 to 6.5 feet, with water depths of 2.5 to 4 ft. A plastered cement mortar lining 2 inches thick is proposed to prevent seepage losses.

Pipe Lines: The Coyote River crossing and conduit along Highway to Laguna Seca Hills, principal road crossings, and all locations where a covered gravity or light pressure conduit is required, will consist of plain or reinforced concrete pipe. Wherever pressure siphons or pipes are required either riveted steel or banded wood stave pipe will be used.

Pumping Plants: The pumping plants at Almaden and Reed Avenues will be designed for maximum efficiency under fixed heads, using horizontal centrifugal pumps direct connected to electric motors. The capacity of the Almaden plant will be 20 cu. ft. per sec. and of the Reed Ave. plant, 10 cu. ft. per sec., each plant having a standby, or emergency unit.

3. SPREADING WORKS ON STREAM CHANNELS

A description of the proposed works and their location is given in Chapter IV. Further details as to plans are given on Plates 67 to 69.

4. CENTRAL PUMPING PLANTS

Palo Alto Division:

The water lacking to supply the demands of the Division from gravity sources will be supplied from a central pumping plant located about as shown on map (Plate 70). This central pumping plant will derive its water from a pipe line skirting the edge of the marsh land of the Bay, into which will feed a number of individual well pumping plants scattered over a wide area. The estimated number of wells required for this development is about twenty, with an assumed average delivery per well of 1 cu.ft. per sec. The wells will be spaced about one-quarter mile apart along a line East and West cross cutting the Valley, in order to distribute the draft uniformly over a wide area and intercept most efficiently the final return water from the upper valley which would otherwise pass to the Bay beyond the limits of beneficial use. Each will be equipped with a deep well vertical turbine pump, direct connected to a vertical electric motor and equipped with remote control. The well pumps will discharge into a common pipe line about five miles in length, and varying in diameter from 20 inches to 34 inches, leading to a central pumping plant at the eastern boundary of the Division.

The central pumping station will boost the water delivered from the wells to the higher levels, with a maximum lift of about 50 feet. This station will be equipped with high grade, high efficiency horizontal centrifugal pumps, direct connected to electric motors.

Milpitas Division

The entire source of water supply for this Division will be a group of wells delivering to a central pumping station as just described for Palo Alto. The number of wells required is estimated to be eighteen, with average delivery of 1.00 cubic feet per second. The length of pipe line to main pump station and pump station to the 100 contour is estimated at 4-3/4 miles, with diameters from 20" to 30".

This pump station will be located about one mile North of Milpitas on the State Highway, as shown on map. From the pump station water will be lifted to the 100 ft. contour, along which conduits will run North and South to the boundaries of the Division. At the Calaveras Road a boosting pump station will lift 5 cubic feet per second of water to the 225 ft. level to supply a canal running South along the hills to Milpitas Road and irrigating land above the 100 ft. level.

ESTIMATES OF COST

GENERAL

The following general estimates of cost are based on the foregoing general layout for the proposed system to conserve and deliver water under a comprehensive plan throughout the entire valley.

QUANTITIES

Quantities for the dams have been calculated from direct surveys or furnished maps, and are subject to confirmation or

revision, or change of type, resulting from the detailed borings and studies not now practicable for lack of funds. The types and quantities are believed, however, to be such as to represent the maximum of cost. This also applies to accessories, detailed designs of which have not been attempted.

Available topographic maps have been used as the basis for locating canals and other conduits, and determining their lengths. Personal inspection has been made of these locations on the ground, to determine general character of material, conditions affecting construction, etc. Quantities have been calculated from actual designs for each conduit, and an average per mile for each size and type of conduit determined.

UNIT COSTS

The unit costs throughout are those selected as being justified by present known construction costs based on present prices for materials and labor.

The cost of reservoir sites is based on reports of sub-committees of the Conservation Committee.

Pumping Plant cost are based on known costs per horse-power installed for complete installations. The probabilities

are that these prices will be revised slightly downward, if at all, and are a safe basis upon which to project costs for the next few years. The unit costs adopted are as follows:-

DAMS AND RESERVOIRS

Hydraulic fill	.50 cu. yd.
Earth fill, rolled	.75 "
Loose rock fill, measured in dam	1.00 "
Rock excavation, in place	$1.50 to 2.50 "
Trench excavation, in earth	1.00 "
Plain concrete	12.00 "
Reinforced " , facings	15.00 "
" " , structures	$15. to 20.00 "
Man handled rock	3.00 "
Outlet pipes, small, 36" reinf. conc.	10.00 per ft.
" towers	30.00 "
" valves & gates, complete each structure	$2500. to 5000.00.
Berm paving, 4" concrete	.25 sq. ft.
Clearing sites	100.00. per acre
Road changes, average	5000.00 per mile
Property, Unimproved	$50. to 200.00 per acre
" , partially improved and improved	400. " 750.00 "

CONDUITS

Earth excavation, side hill	1.00 cu. yd.
" " , valley	.50 "
Rock excavation, side hill	3.00 "
Concrete lining, 2" thick plastered	.15 sq. ft.
Concrete pipe, 50" to 60", average	10.00 per ft.
Steel pipe, 18" to 34"	$2.75 to 6.40 "
Rights of Way	$100. to 1500.00 per acre
4'x 6' lined tunnel	20.00 per ft.

PUMPING PLANTS

Boosting plants, installed complete,	50.00 per h.p.
Individual well plants, aver. 300' wells and equipped complete, each	7000 .00

MISCELLANEOUS

To provide for contingencies pending detailed surveys and designs, engineering and administration, lost interest etc. during construction, an allowance of 25% has been made on the estimates prepared from the above unit prices.

SUMMARIZED COSTS

Reservoirs

The following summarized estimates have been compiled from the detailed estimates for the various structures.

TABLE 23.

SUMMARY OF RESERVOIR COSTS

Reservoir	Storage Cap. Ac. Ft.	Type Dam	Height Ft.	Crest Length Ft.	Materials Cu.Yds.	Total Cost $	Cost per Ac.Ft. Storage $
Coyote #1	60000	Hyd.Fill	210	1085	1878450	1661300.	27.70
" #2	60000	Rock	150	1020	537170	1080310.	18.00
Uvas	20000	"	130	1180	525000	951800.	47.60
Llagas	20000	"	125	800	357300	708600.	35.48
Calero	9000	Hyd.Fill	90	800	420740	380000.	42.20
Almaden	2500	Concrete	110	445	5540	135000.	54.00
Guadalupe #1	3500	Rock	125	580	121850	377170.	107.70
Calabazas	1600	Hyd.Fill	108	480	187060	183595.	114.70
Stevens #1	4000	"	107	860	385200	350000.	87.50
" #2	2000	Concrete	125	410	5140	146000.	73.00
" #3	600	Hyd.Fill	65	430	83815	114000.	190.00
Permanente, S.F.	1170	"	85	600	231050	189000.	161.00
" N.F.	1100	"	85	480	179470	165020.	150.00
San Antonio	1000	"	55	615	138250	148000.	148.00
Madera	5300	Rock	105	500	119610	290000.	54.70

Total Cost of Reservoirs .... $6,879,795.

Cost of storage per acre foot, average, ... 35.87

Reservoir Connecting Conduits

Almaden to Calero
3-1/4 miles canal and 4000 ft. tunnel — 165,000.00

Stevens #2 to Calabazas
1½ miles Canal — 30,000.00

Los Trancos to Madera
Diversion Weir — 5000.
1-½ Miles Canal — 22500. — 27,500.00

$242,500.00

Conduits and Pumping Plants

Morgan Hill - Gilroy Division (Item s (a) to (g)	$533000.
Coyote and West Side Divisions	
Items (a) to (g) Coyote Res. to point Santa Teresa Hills	644700.
Items (H) to (i) Santa Teresa Hills to Stevens Creek on 200 ft. level	343000.
Items (j) to (l) Santa Teresa Hills to High Level Canal on West Side	69000.
Items (a) to (d) High Level West Side Alamitos to Stevens Creek	467000.
(e) and (f) Calabazas to Campbell and Stevens Creek	87200.
(g) Stevens to Permanente and Permanente to San Antonio Creek	127200.
Palo Alto Division	
High Level conduit from San Antonio and Madera Creeks	66250.
Wells, pumping plants, pipe lines, lands and rights of way	490400.
Evergreen Division	
Items (a) to (d) Coyote Diversion to Milpitas Lane	232000.
Milpitas Division	
Wells, pumping plants, pipe lines, lands and rights of way	495450.
Total	$ 3,555,200.

Spreading Dams

Los Gatos No. 1	109000.
" No. 2	57500.
Guadalupe	53500.
Check Dams	50000.
TOTAL	270000.

GENERAL SUMMARY ENTIRE PROJECT

Reservoirs and Connections	$ 7122295.
Conduits and Pumping Plants	3555200.
Spreading Dams	270000.
GRAND TOTAL	$10947495.
Cost Per Acre (157,550 Ac. Gross)	$ 69.50

CHAPTER Vll.

ORGANIZATION AND PROCEDURE.

(By L.D. Bohnett, Attorney, Santa Clara Valley Water Conservation Committee).

The question of organization to carry on the work of developing the waters of Santa Clara Valley and the watersheds tributary thereto is not without its difficulties. We have a highly developed territory, large areas of which are already irrigated to some extent, and some of which is abundantly watered. Conditions are very different in several respects from those existing in the large interior valleys of the state, where most of the irrigation districts of California have been organized. As existing legislation relative to irrigation districts was naturally framed largely to meet conditions existing in these large valleys, and in the comparatively undeveloped sections thereof, it is hard to make that legislation fill local needs.

It is evident that water sufficient for the irrigable portion of Santa Clara Valley cannot be developed from one source. All available sources should be utilized. Existing legislation is expressly drawn for the organization into a single district of land which can be watered from a common source. Consequently a number of districts will probably have to be organized in Santa Clara Valley if no new legislation can be obtained. A number of districts would undoubtedly add to the difficulty of a complete development of the water of the county as there would naturally be a tendency for each

district to appropriate to its own use as much water as possible. A single district under the supervision of one board of directors would seem to be necessary for the complete and harmonious development of our waters.

Another reason why it is believed that the existing law for the organization of irrigation districts would not be favored by the orchardists of Santa Clara Valley is that it provides for uniform taxation upon assessed land values, exclusive of improvements, except that land within a district having its own water supply is taxed only for the payment of interest on bonds.

To meet these difficulties Senate Bill No. 192 has been introduced in the state legislature by Senator Jones. This bill provides that an irrigation district to be known as " Santa Clara County Irrigation District" be organized with boundaries as indicated in the foregoing report (See Plate 70) but only upon approval of a majority vote at an election to be held at which all electors within the boundaries of the proposed district will be entitled to vote. The district, if organized, will have seven directors, elected by the voters of the several subdivisions of the district outlined in the bill. The board of directors will have general supervision of the affairs of the district.

No storage or other development project can be undertaken by the directors without the favorable vote of the landowners affected. The territory to be benefitted by the proposed development must first be outlined by the engineers and the estimated cost apportioned by disinterested assessors to the several parcels of land within this area

SAN MATEO COUNTY
SAN FRANCISCO BAY
ALAMEDA COUNTY
PALO ALTO
WEST SIDE
ALVISO
EVERGREEN
COYOTE
MORGAN HILL
GILROY
SANTA CLARA COUNTY
SAN BENITO COUNTY
LEGEND
Proposed Distribution Conduits.
District and Division Boundary Lines.
Proposed Main Pumping Plants.
Proposed Well Pumping Plants.
SANTA CLARA VALLEY WATER CONSERVATION PROJECT.
PROPOSED DISTRICT
DISTRICT DIVISIONS AND WATER DISTRIBUTION
SANTA CLARA CO., CALIF.
U.S.G.S. Datum.
Contour Interval 5 Feet.
Scale
1 3/4 1/2 1/4 0 1 2 3 MILES
Fred H. Tibbetts.
CONS. ENG'R.
Stephen E. Kieffer.
CONS. ENG'R.
March 1921.

PLATE 70

according to the benefits to be received. An election must then be held within the territory to be benefitted, at which election each owner of land will be entitled to one vote for each dollar of the estimated cost he will be obliged to pay according to the apportionment already made. If a majority of the votes cast favor the project, the development must be undertaken by theboard of directors. At the same election the voters will determine whether the cost of the development shall be met by direct assessment or by a bond issue.

Expenses of the district other than for development purposes, that is the "overhead" expenses, will be paid by an assessment upon all property within the district. The board of directors will furnish the board of supervisors each year an estimate of the amount of money necessary for the ensuing year and the supervisors will fix the tax rate, which will probably always be low. Taxes for the general fund of the district will be collected by the county tax collector with the county taxes and the money will be paid to the county treasurer and paid out upon warrants of the county auditor upon request of the board of directors.

Many details of the proposed law are necessarily omitted from this brief outline. It is hoped that those interested will obtain copies of the bill without delay and that a general study and discussion of the bill will show wherein it may be improved so that when enacted it will be "workable" as may be. Time is limited and suggestions for changes should be made at the earliest possible moment. We believe that we have outlined a valid, practicable and effective form of organization, but we want the help of all interested parties in perfecting the plan.

the following: -

Frank A. Nikirk	A. M. Betague
J. A. McCall	P. McMillan
I. H. Larsen	O. Kohner
J. B. Hodges	W. R. Maring
C. A. Gunner	A. C. Schaffner

The writers wish to especially acknowledge the assistance and co-operation of Dr. S. Fortier and Mr. Frank Adams, of the Irrigation Investigations of the U. S. Department of Agriculture, particularly for access to the original notes of the numerous important investigations in this locality under their supervision.

Mr. H. L. Haehl, formerly of the Bay Cities Water Company, who has made a most exhaustive study of the hydrography, especially of the eastern side of the Valley, has given freely of his time and knowledge of the subject, and has provided the use of a large amount of invaluable data collected under his supervision.

Mr. A. E. Roth, Comptroller of Stanford University, has allowed the use of important data on the San Francisquito Watershed. Dr. J. C. Branner, of Stanford University, furnished numerous records of well logs, and Mr. W. S. T. Smith furnished valuable data on San Antonio Creek.

Mr. Irving L. Ryder, County Surveyor, has contributed especially to the early start of the field work by furnishing excellent maps of the area covered.

The citizens and land owners of Santa Clara Valley owe the greatest debt of gratitude to the members of the Santa Clara Valley Water Conservation Committee, who, without compensation, have given freely of their time and energy toward the preparation of this report as a contribution to the solution of the most important problem ever faced by Santa Clara Valley.